Anne Arundel County Public Schools

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Earth Space Systems Science

Unit 4: The Geosphere

Earth/Space Systems Science
Unit IV: The Geosphere

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Earth/Space Systems Science
Unit IV: The Geosphere

Description

Geology, or "study of the Earth," illustrates the unifying concept among the spheres. Forces deep within the Earth move continents and create giant mountain ranges that are then slowly eroded away, as weathering and erosion demonstrate the interaction among the elements of the hydrosphere and atmosphere. The face of our planet is constantly changing, illustrating the dynamic systems driving our planet. By examining the changes that occur in the geological formations on the crustal surface, we can obtain clues to the interior workings of the Earth.
In this unit, "The Geosphere," students will examine the internal structure of the Earth and its relationship to the geological features of the lithosphere. They will explore the theory of plate tectonics and evaluate the relationship among earthquakes, volcanoes, and plate movements. Through planetary geochemical cycles, mountains are built and later weathered and eroded into sedimentary rock by interactions with wind and water. These small pieces of rock may eventually be carried to the sea floor, where they are pulled under. Many of these fragments will reform as igneous rock in an active volcano, or as cooling magma within the earth.
Ice ages come and go, changing the shape of the land and the biota it supports. Meteor impacts and massive volcanic eruptions cause mass extinctions and then, adaptive radiation as life begins anew. Throughout it all, the face of our planet holds a record of past events. Examining the geologic record is like reading the pages of a fascinating and ever changing book. New technologies help answer long-standing questions about the dynamic processes that guide our planet.

Key questions for this unit are:

1. What is the origin and structure of rocks and minerals?
2. How do constructive and destructive processes alter landforms?
3. How does the theory of plate tectonics illustrate the geochemical cycles that regulate the earth’s dynamic crust?
4. What geologic principles are used to date Earth’s geologic history?
5. What major events delineate geological time units?

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Key Concepts

- The outward transfer of earth's internal heat drives convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe. (NSES p.189)
- The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid earth, oceans, atmosphere and organisms as part of geochemical cycles. (NSES p.189)
- The formation, weathering, sedimentation and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change. (AAAS p.74)
- Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the know decay rates of radioactive isotopes present in rock to measure the time since the rock was formed. (NSES p.189)
- The slow movement of material within the Earth results in heat flowing out from the deep interior and the action of gravitational forces on the regions of different density. (AAAS p.74)
- The solid crust of the earth- including both the continents and the ocean basins- consists of separate plates that ride on a denser, hot, gradually deformable layer of the earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in others. Ocean-floor plates may slide under continental plates, sinking deep into the earth. The surface layers of these plates may fold, forming mountain ranges. (AAAS p.74)
- Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands. (AAAS p.74)

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- Interactions among the solid earth, the oceans, the atmosphere and organisms have resulted in the ongoing evolution the Earth system. We can observe some changes such as eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years. (NSES p.190)

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CONTENT OUTLINE

The Geosphere

I. Origin and Structure of Rocks
   - A. Structure of Matter
     1. atoms
     2. molecules
     3. isotopes
   - B. Common rock forming mineral groups
     1. chemical composition
     2. origin/constructive processes
        - a) cooling/crystallization
        - b) lithification
        - c) deformation
        - d) volcanism
        - e) metamorphism
        - f) deposition
     3. texture
        - a) crystal size
        - b) shape
     4. mineral composition of common rock groups
   - C. Physical Properties
     1. density
   - D. Destructive Processes
     1. weathering
     2. erosion
     3. subsidence
     4. melting
   - E. Landform Change
     1. surface water

2. groundwater
3. glacial processes
4. desert processes
5. coasts

II. Geological Principles
- A. Relative dating
  1. superposition in rock columns
  2. core samples
  3. unconformities
  4. uniformitarianism
  5. cross-cutting relationships
  6. correlation of rock layers
  7. fossil
- B. Absolute dating
  1. radioactive dating

III. Continental Drift
- A. Evidence
  1. rock layers
  2. mineral deposits
  3. climate
  4. fossils
  5. jigsaw

IV. Sea floor Spreading
- A. Evidence
  1. age of seafloor
  2. magnetic reversals
  3. seismic activity
  4. volcanism
  5. mountain building
  6. ocean ridges

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B. Circulation
  1. mantle circulation
  2. outer core circulation

V. Plate Tectonics
  A. Evidence
    1. crustal plate composition
    2. seismic activity
    3. volcanism
  B. Plate Boundaries
    1. divergent
    2. convergent
    3. transform fault
    4. subduction zone
  C. Plate Features
    1. trenches
    2. island arcs
    3. mountain building
  D. Mantle Circulation

VI. Events in Earth's History
  A. Geologic time
    1. scale
    2. magnitude
  B. Time periods
    1. era
    2. period
    3. epoch

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Lesson	Title	90-Minute Blocks
1	Rock-Forming Minerals	One
2	Volcanism	One
3	Igneous Rock	One
4	Weathering	One
5	Factors Affecting Erosion	One
6	Groundwater, Aquifers, and Land Subsidence	One
7	Coastal Landforms	One
8	Glacial Erosion and Deposition	One
9	Wind Erosion and Desertification	One
10	Sedimentary Rock	One
11	Relative Dating	One
12	Cross-Cutting Relationships and Correlation	One
13	Radioactive Decay and the Geologic Time Scale	One
14	Continental Drift	One
15	Seafloor Spreading	One
16	Metamorphism and The Rock Cycle	One
17	Earthquakes: Time-Travel Graphs and Epicenters	One
18	Theory of Plate Tectonics	Two
19	Mountain Building	One
Approximate Number of Time Blocks		20

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Materials per group of four

Alum solution
Aluminum foil
Aluminum foil tray, small
ArcView Computer Program
Balance
Bar magnets - 2
Bathymetric map - 4
Beaker, 250 mL - 4, 400 mL – 3, 500 mL
Bowen's reaction series chart
Broom
Cake decorating supplies and sprinkles, assorted
Calculator
Calculator-2,
Carbonated water
Clay – 4 colors
Colored pencils
Compasses - 2
Crayons, red or orange
Diagram of Earth's internal structure
Dissecting tray
Envelope labeled "Set A:
Envelope labeled "Set B"
Filter paper
Food coloring, red, blue
Geologic event cards
Geologic time scale-2
Glass or plastic tubing (1 cm x 15 cm)
Glass square
Gloves
Glucose solution
Glue
Graduated cylinder, 100 mL
Graph paper
Graphing calculator
Grass
Gravel
Grease pencil
Gum drops
Hair dryer
Hand lens
Hot plate
Hydrogen chloride (HCl) .1M
Ice
Ice cream, vanilla
Iodine solution
Iron filings
Jar, clear with lid
Limestone, Crushed
Magnetite – 2 pieces
Map of North America-4
Marshmallows
Measuring tape
Mentos mints
Microscope
Microscope slide of diatoms,
Microscope slides - 3
Mineral samples - 5
Mohs hardness scale
Molasses
Nail
Nickels - 32
Paint tray
Paper – 2 pieces
Paper towels
Pebbles or gravel
Pennies - 32
Petri dish, plastic - 4
Plastic bottle with cap
Plastic cups, clear
Plastic knife
Ring stand
Rock samples - 5
Rocks, igneous – 1 or 2
Rocks, sedimentary – conglomerate, breccia, sandstone, shale, rock with fossils
Rocks, small
Ruler (metric)
Salt solution
Sand – assorted colors
Sand (coarse, medium, fine)
Scissors
Seafloor map-2,
Sequence cards – nonsense letters
Sequence cards – sketches of fossils
Slinky
Soil
Spoon
Steel file
Steel wool
Stereoscope
Stirring rod
Straw or tubing
Streak plate
Sugar
Terrarium or shoebox, small, clear plastic
Timer
Toothpicks
Topographical world map
Transparencies of polar wander curve diagrams - 2
Vial and lid
Water
Wax
Wax paper
Wooden blocks – 2 small
World map with plate boundaries-4

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Lesson 1: ROCK-FORMING MINERALS

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

Indicator(s): Core Learning Goal 2

2.4.1 The student will compare the origin and structure of igneous, metamorphic and sedimentary rocks. Assessment limits (at least) - Structure of matter (atoms, molecules, isotopes), Physical properties (density) and chemical composition of common rock forming mineral groups, Origin, texture (crystal size, shape) and mineral composition of common rock groups

Student Outcome(s):

1. The student will be able to identify minerals by analyzing their physical properties.
2. The student will be able to describe the chemical composition of rock-forming minerals by reading a technical selection and making molecular models.

Brief Description:

In this lesson, students compare rocks and minerals and review that rocks are made of minerals. Through tests they identify the physical properties of minerals and begin to learn their chemical composition.

Background knowledge / teacher notes:

"Common Rock-forming Minerals

While rocks consist of aggregates of minerals, minerals themselves are made up of one or a number of chemical elements with a definite chemical composition. Minerals cannot be broken down into smaller units with different chemical compositions in the way that rocks can. More than two thousand three hundred different types of minerals have been identified. Luckily many are rare and the common rocks are made up of a relatively small number of minerals.

Identifying the common minerals

Since minerals are the building blocks of rocks, it is important to identify the most common varieties. Minerals can be distinguished using various physical and/or chemical characteristics, but, since chemistry cannot be determined readily in the field, geologists use the physical properties of minerals to identify them. These include features such as crystal form, hardness (relative to a steel blade or your finger nail), color, luster, and streak (the color when a mineral is ground to a powder). Generally, the characteristics listed above can only be determined if the mineral grains are visible in a rock. Thus the identification key distinguishes between rocks in which the grains are visible and those in which the individual mineral components are too small to identify.

The six minerals olivine, quartz, feldspar, mica, pyroxene, and amphibole are the most common rock-forming minerals and are used as important tools in classifying rocks, particularly igneous rocks. Except for quartz, all the minerals listed are actually mineral groups. However, instead of trying to separate all the minerals that make up a group, which is often not possible in the field, they are dealt with here as a single mineral with common characteristics.

- Quartz is a glassy looking, transparent or translucent mineral that varies in color from white and gray to smoky. When there are individual crystals they are generally clear, while in larger masses quartz looks more milky white. Quartz is hard - it can easily scratch a steel knife blade. In many rocks, quartz grains are irregular in shape because crystal faces are rare and quartz does not have a cleavage (i.e., it does not break on regular flat faces).
- Feldspar is the other common, light-colored rock-forming mineral. Instead of being glassy like quartz, it is generally dull to opaque with a porcelain-like appearance. Color varies from red, pink, and white (orthoclase) to green, gray and white (plagioclase). Feldspar is also hard but can be scratched by quartz. Feldspar in igneous rocks forms well developed crystals that are roughly rectangular in shape, and they cleave or break along flat faces. The grains, in

contrast to quartz, often have straight edges and flat rectangular faces, some of which meet at right angles.

- Mica is easily distinguished by its characteristic of peeling into many thin flat smooth sheets or flakes. This is similar to the cleavage in feldspar except that in the case of mica the cleavage planes are in only one direction and no right angle face joins occur. Mica may be white and pearly (muscovite) or dark and shiny (biotite)
- Pyroxene: The most common pyroxene mineral is augite. Augite is generally dark green to black in color and forms short, stubby crystals, which, if you look at an end-on section, have square or rectangular cross-sections.
- Amphibole: The most common amphibole is hornblende. Hornblende is quite similar to augite in that both are dark minerals, however hornblende crystals are generally longer, thinner and shinier than augite and the mineral cross-sections are diamond-shaped.
- Olivine, or *peridot* in the jewelry trade, is yellow-green, translucent and glassy looking. Crystals are not common; it usually occurs as rounded grains in igneous rocks or as granular masses. Olivine is almost as hard as quartz; it does not have a well-developed cleavage.
- Quartz and feldspar are light-colored minerals; mica, pyroxene, amphibole and olivine are dark-colored. The proportions of light and dark-colored minerals present will determine the color of a rock. If most of the grains are quartz and feldspar then the overall appearance of the rock will be light, while the opposite will be true if the minerals are mainly mica, pyroxene, amphibole or olivine. The color of a rock with between 25 and 50% dark minerals is intermediate.
- Calcite is a very common mineral in sedimentary rocks. It is commonly white to gray in color. Individual crystals are generally clear and transparent. Calcite is softer than quartz and can be scratched easily by a steel knife blade. In a rock, calcite grains are often irregular to rhomb-like in shape. Calcite's major distinguishing characteristic though is its vigorous reaction with dilute hydrochloric acid. Dolomite is very similar to calcite but does not react well with acid unless powdered first.
- Clay minerals are very fine-grained and difficult to tell apart in the field. They can vary in color from white to gray, brown, red, dark green and black. Clays are plastic and often sticky when wet; they feel smooth when smeared between the fingers.

- Magnetite is common in igneous and metamorphic rocks, and some sediment, though usually in only small amounts (1 - 2 %). It is black in color with a metallic luster, occurring in small octahedral (like two pyramids stuck together). Easily recognized by its strongly magnetic character.
- Pyrite: the most common sulfide mineral, i.e. those minerals containing sulfur as a principle component. It occurs in all rock types, though usually only in small amounts. It is a pale brassy yellow in color with a metallic luster and often forms cube-shaped crystals, also known as "fool's gold."
- Talc occurs in granular or foliated masses sometimes known as *soapstone*. It is white to green, sometimes gray or brownish. It is very soft and will be scratched by a fingernail. It has a greasy feel."

From the Ministry of Energy & Mines. British Columbia. *Common Rock-Forming Minerals*. Available: http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/InfoCirc/Ic1987-5/rockmin.htm

Teacher note: The densities of common minerals may be found in the website.
David Barthelmy. *Mineralogy Database.*
Available: http://webmineral.com/determin/metallic_minerals_by_density.shtml

Chemical classification of Common Rock Forming minerals	
Native elements (metal) · native gold (Au) · native copper (Cu) · native sulfur (S) · native silver (Ag)	**Hydroxides** (metal + OH) · limonite (iron hydroxide) · bauxite (aluminum hydroxide)

· graphite (C) · diamond (C)	
Sulfides (metal + S) · pyrite (FeS2) · galena (PbS) · sphalerite (ZnS)	**Carbonates** (metal + CO_3) · calcite (CaCO3) · dolomite (CaMg(CO3)2)
Sulfates (metal + SO_4) · gypsum (CaSO4 · 2H2O) · anhydrite (CaSO4) · barite (BaSO4)	**Phosphates** (metal + PO_4) · apatite
Oxides (metal + O) · water ice (H2O) · hematite (Fe2O3) · magnetite (Fe3O4) · corundum (Al2O3)	**Other - borates, urananates**
Halides (metal + Cl or F halogens) · halite (NaCl)	**Silicates** (metal + Si and O) · quartz (SiO2)

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· fluorite (CaF_2)	· potassium feldspar ($KAlSi_3O_8$) · Ca Plagioclase feldspar ($CaAl_2Si_2O_8$) · Na Plagioclase feldspar ($NaAlSi_3O_8$)

From Georgia Perimeter College. *Introduction to Minerals*.

Available: http://www.dc.peachnet.edu/~pgore/geology/geo101/mineral.htm#Chemical

Lesson Description:

ENGAGE	Give each small group of students a selection of rocks and minerals. Directions: 1. Separate the samples into rocks and minerals. 2. What characteristics did you use to make the decision? 3. Present your selection to the class and explain what characteristics you used to make the selection. Discussion: Write the characteristics on the board. Narrow them down to four. Scientists use four criteria to determine whether or not a substance is a mineral: · Is the substance inorganic? · Does the substance occur in nature? · Is the substance in a solid crystalline form? · Does the substance have a definite chemical composition? As a class, examine the mineral samples and generate a list of properties that could be used to identify the mineral. *Identification properties: color, hardness, luster, streak, cleavage*

	or fracture, crystal shape, density, and reaction with HCl. Adaptive Strategy: View part of the PowerPoint presentation on minerals and their properties. Mt. San Antonio College. *Minerals.* Available: http://www.mtsac.edu/~mboryta/esci/Minerals/index.html
EXPLORE	Working in small groups, students conduct mineral tests and determine the identity of minerals. Materials per lab group: copper penny, glass square, mineral samples (five), steel file or nail, streak plate, hand lens, graduated cylinder, balance, ruler, Mohs Scale of Mineral Hardness, .1M HCl For mineral test directions, see resources or for detailed instructions and images visit Georgia Perimeter College. *Introduction to Minerals.* Available: http://www.dc.peachnet.edu/~pgore/geology/geo101/mineral.htm#Chemical Teacher Note: Mineral samples should be calcite, gypsum, halite, and silicates (such as olivine, mica, feldspar or quartz) ***Journal Write:*** 1. Design a data table to record the results of the mineral tests. 2. Determine the identity of minerals using a mineral identification key. Adaptive Strategy: Help students design a data table using the properties of a mineral. Choose one mineral and model each mineral test using a think-aloud.

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	Teacher Note: A mineral identification key may be found in Holt, Rinehart, and Winston. (1998). Modern Earth Science, In-depth Investigation: *Mineral Identification.* pp. 43-48. Or other similar texts.
EXPLAIN	Have groups exchange minerals and completed data tables. Using the completed data tables and mineral identification key, students identify the minerals.
EXTEND	Do a Think-Pair-Share 1. Give each student a rock containing easily seen minerals. 2. Examine the rock. Are there minerals present? *yes* 3. What evidence do you have to support your answer? *Crystals, colors, luster…* Teacher-led discussion: Some minerals are so abundant in rocks, they are called "rock-forming minerals." The majority of rock-forming minerals are made from combinations of the same eight elements: Oxygen (O), Silicon (Si), Aluminum (Al), Iron (Fe), Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg) Silicon and oxygen form the building block for silicates, the largest group of minerals, silicates Adaptive Strategy: Review the differences between elements and compounds using the PowerPoint presentation. Mt. San Antonio College. *Minerals.* Available: http://www.mtsac.edu/~mboryta/esci/Minerals/index.html Using manipulatives such as marshmallows, gumdrops, and toothpicks, students build a silicon-oxygen tetrahedron. Remind students that silicon has 4 electrons in its outer shell, and oxygen has six.

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	Adaptive Strategy: Review the difference between atoms and molecules and how to interpret chemical formulas such SiO_4. If students have difficulty building the model, show them a diagram of SiO_4. For diagram see: Glencoe McGraw-Hill. (2002). Glencoe Earth Science, Geology, the Environment, and the Universe. p. 81. Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. p. 20. Or other similar text passages may be used. Working in small groups, challenge students to build other silicates using SiO_4 as the basic building block. *Students should be able to form chains or hexagons* Adaptive Strategy: Model how to combine two molecules of SiO_4. Read to be informed about the chemical composition of rock-forming minerals: Create a graphic organizer to record the physical properties and chemical composition of the major rock-forming mineral groups: Silicates, carbonates, oxides, halides, sulfates, native elements, hydroxides and phosphates Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 19-21. Or Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment and the Universe. pp. 80-83. Or other similar text passages may be used. Teacher Note: Students only need to know the chemical

	composition of the general mineral group (silicates: silica and oxygen) not the chemical composition of individual minerals. Adaptive Strategy: Show students how to interpret chemical formulas such as those found in the teacher background to help them classify mineral and determine the overall chemical composition of mineral groups. ***Journal Write:*** For each of the following mineral groups state the chemical composition and a physical property: silicates, carbonates, oxides, halides, sulfates, native elements, hydroxides and phosphates INTEREST CENTER Take a tour of a house and see the many uses of minerals. Ontario Mining Association. *Minerals and Metals at Home!* Available: http://www.nrcan.gc.ca/mms/scho-ecol/tour/intro_e.htm
EVALUATE	***Journal Write***: 1. How do physical properties help us identify minerals? 2. Using information from your graphic organizer, describe the physical properties and chemical composition of the major rock-forming mineral groups.

Materials per lab group:

- 5 Samples of rocks
- 5 Samples of minerals: calcite, gypsum, halite, and silicates (such as olivine, mica, feldspar or quartz)
- Copper penny
- Glass square
- Steel file or nail

- Streak plate
- Hand lens
- Mohs Hardness scale
- Graduated cylinder
- Balance
- Ruler (metric)
- Hydrogen chloride (HCl)
- Safety goggles
- Manipulatives: marshmallows or gumdrops
- Toothpicks

MOHS SCALE OF MINERAL HARDNESS

MINERAL	HARDNESS	SIMPLE TEST
Talc	1	Easily scratched by fingernail
Gypsum	2	Scratched by fingernail
Calcite	3	Scratched by copper penny Reacts with HCl
Fluorite	4	Easily scratched by steel
Apatite	5	Scratched by steel
Orthoclase Feldspar	6	Scratches glass with difficulty
Quartz	7	Scratches glass and steel
Topaz	8	Scratches quartz
Corundum	9	No simple test
Diamond	10	No simple test

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Lesson 2: VOLCANISM

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.6 The student will read a technical selection and interpret it appropriately.

1.7.5 The student will investigate career possibilities in the various areas of science.

Indicator(s): Core Learning Goal 2

2.4.1 The student will compare the origin and structure of igneous, metamorphic and sedimentary rocks. Assessment limits (at least) - Origin, texture (crystal size, shape) and mineral composition of common rock groups

2.4.2 The student will explain how the transfer of energy drives the rock cycle. Assessment limits (at least) - Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition)

Student Outcome(s):

1. The student will be able to explain how volcanism is a constructive process by observing the formation of a volcanic island and reading a technical article.
2. The student will be able to analyze factors that affect the strength of volcanic eruptions by performing laboratory investigations.

Brief Description:

In this lesson, students explore what factors influence the strength of eruptions and why volcanic eruptions are constructive processes.

Background knowledge / teacher notes:

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Volcanoes erupt because of density and pressure. The lower density of the magma relative to the surrounding rocks causes it to rise. Magma will rise to a depth determined by the density of the magma and the weight of the rocks above it. As the magma rises, bubbles start to form from the gas dissolved in the magma. The gas bubbles exert tremendous pressure. This pressure helps to bring the magma to the surface and forces it in the air, sometimes to great heights.

The two main factors that influence how a volcano erupts are viscosity and gas content. Both are related to the composition of the magma. Hawaiian volcanoes tend to erupt basalt, which is low in viscosity and low in gas content (about 0.5 weight percent). The gas that is present can readily escape and little pressure builds up in the magma. At the other extreme, rhyolite magmas are very viscous and can contain a lot of gas (up to 7-8 weight present). As the magma moves into the vent and the pressure drops, the gas wants to escape. The magma is very sticky and resists the expansion of the gas bubbles. Ultimately, enough bubbles grow and expand to blow the magma into ash size fragments and eject them violently into the atmosphere.

Modified from Volcano World. *Ask the Volcanologist.*

Available:

http://volcano.und.nodak.edu/vwdocs/frequent_questions/top_101/Eruption/Eruption1.html

Lesson Description:

ENGAGE	Technology Connection: View a video clip or slide show of a volcano erupting. Adventures Gallery. *Hawaii volcano.* Available: http://www.adventuregallery.net/GBradLewis.htm National Geographic Society. *Born of Fire: Plate Tectonics.* (Video). Shows the birth of the Island of Surtsey. National Geographic Society. *Volcano: Nature's Inferno.* (Video). Or other similar video clips. Discussion:

	1. Where does the lava come from? *Inside the asthenosphere or mantle* 2. What is the difference between magma and lava? *Lava is magma that has reached Earth's surface.* 3. What happens to the lava or magma? *Eventually it cools and solidifies forming rock. A process called crystallization.* 4. What type of rock is formed from the lava? *Igneous*
EXPLORE	Read a short article on the formation of Surtsey or other volcanic island. Jorgen S. Aabech. *Surtsey, Iceland.* Available: http://www.vulkaner.no/v/volcan/surtsey_e.html Take a look at some of the formations made by cooling lava. Good Earth Graphics. *The Virtual Cave. Lava Tube Caves.* Available: http://www.goodearthgraphics.com/virtual_tube/virtube.html
EXPLAIN	***Journal Write:*** 1. Why is volcanism a constructive process? 2. Use evidence from the video and reading to support your answer.
EXTEND	Technology Connection: View the simulation of a volcanic eruption. CNN. *CNN.Com Anatomy of a Volcano.* Available: http://www.cnn.com/interactive/nature/0003/volcano/frameset.exclude.html Brainstorm 1. What causes a volcano to erupt? 2. Why are some eruptions gentle while others violent? *Temperature,*

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	composition of magma, pressure or the amount of dissolved gasses in magma. Materials per lab group: plastic bottle with cap, “flat” water, Menthos mints, carbonated water, hot plate, molasses, paper towels, beaker ***Journal Write:*** 1. Write a hypothesis about the effect of dissolved gases on the violence of the eruption. 2. Write a hypothesis about the effect of pressure on the violence of the eruption. As a class brainstorm ways to observe the effect of pressure and dissolved gases on the violence of eruptions. Sample procedure 1. Fill the bottle with carbonated water and cap. 2. Remove the cap. Teacher Note: Be sure to test prior to class. Demonstration for outside: To make the above reaction more obvious drill a hole through two Menthos. This can be easily done with a knife. Add Menthos to 2L bottle, replace the lid and run! Wear a raincoat while doing this. Reaction will blow the bottle several feet in the air, the lid will come off and liquid will go everywhere! As a precaution, be sure students stand several yards away and wear safety glasses. ***Journal Write:*** 3. What happened? 4. Replace the cap. 5. Shake vigorously 6. Remove the cap 7. Repeat using “flat” water. ***Journal Write:*** 8. What is the relationship between pressure, dissolved gases and the violence of the eruption?

	<u>G/T Connection:</u> Observe the effect of temperature by heating the carbonated water and comparing the amount of liquid left after the "eruption." Observe the effect of magma composition: 1. Fill the bottle with water 2. Squeeze gently and note the amount of liquid expelled. 3. Empty the bottle and refill with molasses 4. Squeeze gently and note the amount of liquid expelled. Teacher Note: do the investigations over a sink or tray. <u>Adaptive Strategy</u>: Do the above activities as a teacher demonstration. <u>G/T Technology Connection:</u> How does volcanism on other celestial bodies compare to that on Earth? Read one or two of the following articles: Robert Wickman. *Volcanism on the Moon.* Available: http://volcano.und.nodak.edu/vwdocs/planet_volcano/lunar/Overview.html Robert Wickman. *Volcanism on Mars.* Available: http://volcano.und.nodak.edu/vwdocs/planet_volcano/mars/Overview.html MarsDaily.com. *Active Volcanism on Mars.* Available: http://www.spacedaily.com/news/mars-volcano-01a1.html Or other similar text passages. INTEREST CENTER What volcanic activity is occurring this week?

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	Smithsonian. GVP/USGS *Weekly Volcanism Activity Report.* Available: http://rathbun.si.edu/gvp/reports/usgs/index.cfm In Volcano, your goal consists in saving some small villages from deadly lava flows. You must dig or add some land hillocks in order to deviate the flowing process Momor Productions. *Volcano.* Available: http://eicart.free.fr/volcano/ Career Connection: University of North Dakota. *How to become a Volcanologist.* Available: http://volcano.und.nodak.edu/vwdocs/how_to.html University of North Dakota. *Working on Hawaiian Volcanoes.* Available: http://volcano.und.nodak.edu/vwdocs/working_on_volcs/Working_on.html
EVALUATE	***Journal Write***: 1. Why is volcanism a constructive process? Use evidence from the video and reading to support your answer. 2. What factors affect the strength of an eruption? Use evidence from your investigations to support your answer.

Materials per lab group:

- Plastic bottle with cap
- “Flat” water
- Carbonated water
- Hot plate
- Beaker

- Molasses
- Paper towels
- Menthos mints

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Lesson 3: IGNEOUS ROCK

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.7.5 The student will investigate career possibilities in the various areas of science.

Indicator(s): Core Learning Goal 2

2.4.1 The student will compare the origin and structure of igneous, metamorphic and sedimentary rocks. Assessment limits (at least) - Origin, texture (crystal size, shape) and mineral composition of common rock groups

2.4.2 The student will explain how the transfer of energy drives the rock cycle. Assessment limits (at least) - Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition)

Student Outcome(s):

The student will be able to describe the origin, texture and mineral composition of igneous rocks by simulating the formation of igneous rock and interpreting Bowen's reaction series.

Brief Description:

In this lesson, students examine the relationship between cooling rates and crystal size and the formation of different types of igneous rocks.

Background knowledge / teacher notes:

The most common characteristics used to classify igneous rocks are crystal size, color and shape. The crystal size indicates how fast the rock cooled. Since magma is not exposed to the cooling effects of the atmosphere, it cools slowly, allowing large crystals to form. Therefore large crystals (coarse texture) are evidence that the rocks cooled slowly. Rocks formed below the surface and are called intrusive (plutonic) igneous rocks. Conversely, extrusive (volcanic) igneous rocks may have small crystals, or no apparent crystalline structure because lava is exposed to the cooling effects of the atmosphere. This is particularly obvious with obsidian, also known as "volcanic glass."

PowerPoint presentation on rock and minerals
University of Akron. *Internal Structure of the Earth.*
Available: http://www3.uakron.edu/geography/lrb/physf97/lectures/internalstruct/sld015.htm

For all the details about igneous rocks, see University of British Columbia. *Igneous rock.*
Available: http://www.science.ubc.ca/~geol202/igneous/igneous.html

Bowen's Reaction Series

"The first thing we notice is that there are two sides, or branches, to the series. The left side is called the discontinuous branch; the right side is the continuous branch. The right branch of the series is composed of only one mineral, plagioclase. As the melt cools the first minerals to crystallize are the plagioclase that are calcium rich (anorthite). As more cooling occurs the plagioclase crystals continually react with the melt, changing composition until reaching the sodium rich end member of the series (albite). Calcium rich plagioclase is associated with more mafic igneous rocks (gabbros and basalts), while the sodium rich plagioclase is associated more with felsic rocks (granite and rhyolite).

On the left branch we have four minerals (olivine, pyroxene, amphibole, and biotite) that form a discontinuous reaction series. Each of these minerals is distinct from one another in composition and structure, but all four are rich in iron and magnesium. As the melt cools, these minerals crystallize out of the melt at specific temperatures; first olivine, then pyroxene and the other minerals. This branch is discontinuous because there is not a solid solution (a mineral halfway between the compositions) of, say, pyroxene and amphibole. The reactions between the crystals and the melt occur only at specific phases of the cooling of the magma. This process continues until there is no melt left for the minerals to react with, so it is possible for the reactions to stop after olivine has formed, or continue all the way to the formation of biotite. Any melt that

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remains after the minerals from both branches crystallize is going to be saturated with silicon, potassium, and aluminum. These will combine to form potassium feldspar or muscovite, and any remaining silica will become quartz."

Adapted from Everyday Geology. *Bowen's Reaction Series.*

Available: http://www.suite101.com/article.cfm/everyday_geology/83762

Teacher note: This site contains a description of how to write an essay on Bowen's Reaction Series. Division of Earth Sciences, University of Glasgow. *Earth Sciences – How to Write an Essay*.

Available: http://www.earthsci.gla.ac.uk/courses/l1/essay-how.htm

Lesson Description:

ENGAGE	Teacher demonstration: Materials: hot plate, aluminum foil tray (small enough to fit on hot plate), red or orange crayons or use wax and red food coloring, one sheet of aluminum foil, water, beaker, stirring rod, sand Directions: 1. Place the crayons in the aluminum foil tray. 2. Using a hot plate, melt wax or crayons. Make sure the melted substance is very runny so it can seep into the sand. If the wax or crayon is still thick when melted, add water and stir. 3. What happens when a volcano erupts? 4. How are igneous rocks formed? 5. Explain that when a volcano erupts some of the magma spills onto the surface. 6. Slowly pour some of the crayon across the aluminum foil so that it flows smoothly and hardens. *Extrusive (volcanic) igneous rock* 7. Partially fill a plastic cup with sand. 8. Explain that sometimes magma remains inside the volcano and

	cools 9. Slowly pour some of the crayon into the cup of sand. *Intrusive (plutonic) igneous rock* Discussion 1. How are igneous rocks formed? *On the surface, extrusive and below the surface, intrusive.* 2. Does the formation cause a difference in the type of igneous rock formed?
EXPLORE	Materials for group of two: intrusive and extrusive igneous rocks, hand lens Give each pair of students several samples of either intrusive or extrusive igneous rock and a hand lens. Directions: 1. All of these rocks belong to the same rock group. Create a graphic organizer to record the characteristics of each rock, such as color, texture, crystalline structure.. 2. Using the hand lens, examine each of the rocks. <u>Adaptive Strategy:</u> Choose one rock and do a think-aloud about its characteristics. Work with small groups to develop a graphic organizer.
EXPLAIN	Students share their observations with a group that had a different type of igneous rock. Using the observations, groups should observe that igneous rocks fall into two groups based on crystal size. ***Journal Write:*** Describe characteristics of igneous rocks. *Intrusive igneous rocks are generally coarse-grained, which is called phaneritic. This means that the crystals are visible to the naked eye. Extrusive igneous rocks are fine-grained, or aphanitic that is, crystals*

	are not visible with the naked eye. In general, light-colored igneous rocks contain a lot of quartz, while dark-colored igneous rocks are low in quartz. Civil and Environmental Engineering University of Berkeley. *Igneous rock.* Available: http://www.ce.berkeley.edu/~khazai/CE70/igneous.html
EXTEND	***Journal Write:*** 1. Write a hypothesis to explain the relationship between rates of cooling and size and number of crystals. 2. Design an experiment to observe the effect of cooling rates on the formation of crystals. Based on Mesa Verde. Earth Science. *Growing Crystals Experiment.* Available: http://powayusd.sdcoe.k12.ca.us/pusdmvms/6thgrade/6SCIENCE/earthscience/EarthStudentActs/Igneous/CRYSTALexperiment.htm Materials: saturated solution such as alum, salt or iodine, 3 plastic petri dishes or microscope slides, ice, beaker, hot plate Sample procedure: 1. Heat solution, but do not boil. 2. Pour solution into petri dishes until the dish is 50% filled or place one drop of solution on microscope slide 3. Place dish or slide in different temperatures: ice bath, room temperature, sunlight or warm area. 4. Using a stereoscope or microscope, observe crystal size and number every few minutes until cooled. ***Journal Write:*** 1. Describe or draw the appearance of your “rocks/crystals.” 2. What is the relationship between the rate of cooling and the formation and size of crystals?

	3. What conclusion can you make about the formation of igneous rocks? Teacher Note: Point out that cooling/crystallization is a constructive process. Adaptive Strategy: Read to be informed about the origin of igneous rocks. Mesa Verde. Earth Science. *Growing Crystals Experiment.* Available: http://powayusd.sdcoe.k12.ca.us/pusdmvms/6thgrade/6SCIENCE/earthscience/EarthStudentActs/Igneous/CRYSTALexperiment.htm Read to be informed about the formation and characteristics of common igneous rock groups: felsic or granitic and mafic or basaltic. Create a graphic organizer to record the origin, crystal size and shape, and mineral composition of the common rock groups. Glencoe-McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. pp. 99-111. Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 32-37. Or other similar text passages. Provide each student with a copy of Bowen's Reaction Series. Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. p. 35. Glencoe-McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. p. 104. James Madison University. *Bowen's Reaction Series and the Igneous Rock Forming Minerals.* Available: http://csmres.jmu.edu/geollab/Fichter/RockMin/RockMin.html

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	Working in small groups, students interpret Bowen's Reaction Series. Adaptive Strategy: This website offers an informal explanation of Bowen's reaction series. GeoMan. *Ask GeoMan...What is Bowen's Reaction Series?* Available: http://jersey.uoregon.edu/~mstrick/AskGeoMan/geoQuerry32.html Technical Connection: Students conduct a simulation to observe the effect of cooling rates on mineral formation and identify the rock group formed. Do not do the fractional crystallization simulation. Simulation located at Florida State University. Geological Sciences. *Bowen's Reaction Series.* Available: http://gly1000-01.su00.fsu.edu/ig/Ig8.html Teacher Note: students need a table containing the characteristics of igneous rocks and Bowen's reaction series diagram. For example: Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. Table 2.1 "Classification of Igneous Rocks" p. 37. Glencoe-McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. Table 5-2 "Classification of Igneous Rocks" p. 107. Adaptive Strategy: View the simulation as a class or work with small groups to discuss the simulation. G/T Connection: Perform the same simulation including the fractional crystallization. Career Connection: Everyday Geology. *Geology as a Career.*

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	Available: http://www.suite101.com/article.cfm/everyday_geology/65366 INTEREST CENTER Department of Geological Sciences. California State. University. *Igneous rock tour.* Available: http://seis.natsci.csulb.edu/basicgeo/IGNEOUS_TOUR.html The activity is designed to let you learn about igneous rocks at your own speed using images of hand samples and rock outcrops in their natural settings.
EVALUATE	***Journal Write***: Write a brief paragraph comparing the origin, texture and mineral composition of felsic or granitic and mafic or basaltic rocks. Use information from your graphic organizer, Bowen's reaction series chart and simulation in your answer.

Materials per lab group:

- Hot plate
- Ice
- Beaker
- Alum solution
- Salt solution
- Iodine solution
- 3 microscope slides
- Stereoscope
- Microscope
- 3 Petri dish, plastic
- Bowen's reaction series chart

Teacher demonstration

- Hot plate
- Aluminum foil tray (small enough to fit on hot plate)
- Red or orange crayons
- Wax and red food coloring
- One sheet of aluminum foil
- Water
- Beaker
- Stirring rod
- Sand

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Lesson 4: WEATHERING

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.3 The student will use experimental data from various investigators to validate results.

1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.

Indicator(s): Core Learning Goal 2

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) - Destructive processes (weathering, erosion, subsidence, melting)

Student Outcome(s):

1. The student will be able to infer the effects of weathering by analyzing the composition of sand.
2. The student will be able to compare mechanical and chemical weathering by designing and performing a laboratory investigation.

Brief Description:

Sediments, such as sand, are the result of chemical and mechanical weathering. Students examine sand samples and attempt to determine where the sand originated, and infer the processes that generated the particles. Students design an experiment to observe how chemical and mechanical weathering break down rocks.

Background knowledge / teacher notes:

Weathering is the slow breakdown of rocks caused by a variety of factors such as water, chemicals, and temperature changes. As the rocks of the continental and oceanic crust break down through the process of weathering, abiogenic or inorganic mineral sands are formed. The continental crust, composed primarily of granite, breaks down releasing the quartz and feldspar. The weathering of oceanic crusts generates basalt and smaller amounts of olivine and obsidian. Erosion, by wind and water, then transports these loose fragments or sediments downstream and eventually to beaches.

When rocks are exposed to chemicals such as those contained in acid rain or acids excreted by plants, the minerals, contained within the rocks, react with the chemicals. Water runs over rocks and minerals are leached from the soil as they dissolve in the water. Carbon dioxide reacts with water to form carbonic acid. When carbonic acid comes in contact with minerals, a chemical reaction may occur. Limestone caves are a good example of this reaction. Even oxygen can affect rocks if they contain iron, causing them to rust.

Lesson Description:

ENGAGE	Show students pictures of a sandy beach and sand dunes. 1998. Picture of Hawaiiguide.com. *Picture of Waimea Bay.* Available: http://www.hcc.hawaii.edu/hawaii/pictures/beach3.gif Park Geology. National Park Service. *White Sands NM.* Available: http://www2.nature.nps.gov/grd/cfprojects/photodb/Photo_Detail.cfm?PhotoID=49 Discussion: 1. Where does sand come from? *Sand is made from the breakdown of rocks and skeletal remains animals.* 2. What is sand?
EXPLORE	Working in groups of four, analyze a sand sample from Maryland. Materials per lab group: four hand lens or stereoscope, four 4cm x 4cm square of black paper, four toothpicks, sand, vial and lid, “What Minerals are in Your Sand Sample?” table Directions: 1. Design a data table to record the minerals present in the sand

	sample. 2. Pour a about a teaspoon of sand onto the black paper. 3. Using the hand lens or stereoscope sort the grains according to color. 4. Examine individual sand grains. Observe their color, shape and texture. 5. Identify the sand grain by matching the type of sand grain to one of the descriptions. 6. Glue the sand grains on to data table.
EXPLAIN	Members of the group share their results. ***Journal Write:*** Describe the composition of your sand. Discussion: 1. Show students rock samples of granite and basalt 2. How did sand form from these rocks? 3. What is this process called? *Weathering.* 4. What is the difference between weathering and erosion*?* *Weathering is the breaking down of rocks while erosion transports the fragments.* <u>Adaptive Strategy:</u> USGS. *What's the difference between weathering and erosion?* Available: http://www.aqd.nps.gov/grd/usgsnps/misc/gweaero.html Teacher Note: Be sure to emphasize that weathering is a destructive process. Think-Pair-Share 1. How does weathering occur in nature? 2. Compile the answers on the board or overhead. 3. As a class, categorize weathering into mechanical and chemical.

	Mechanical weathering: abrasion, ice wedging, and organic actions. *Chemical weathering: carbonation, acid precipitation, oxidation, hydrolysis, and plant acids*
EXTEND	Working in lab groups, design an experiment to investigate either chemical or mechanical weathering. Chemical weathering materials per lab group: 50g limestone chips, water, weak acid such as vinegar, two 400 mL beakers, balance, paper towels Sample procedures: 1. Design a data table. 2. Place 25 g of limestone chips a beaker and cover with water. 3. Place 25 g limestone chips a beaker and cover with weak acid. 4. Let sit at least 10 minutes. 5. Pour off liquid. Blot dry and weigh. G/T Connection: 1. Provide students with soils of different pH levels and soil test kits. 2. Determine the pH of the soil. 3. Run water over the soil and drain 4. Retest the pH of the soil. 5. Describe the effects of chemical weathering. Read to be informed about acid rain and liming. Atlantic Salmon Journal. *Little Progress and a Ray of Hope in the Battle Against Acid Rain Come from Unlikely Sources.* Available: http://www.asf.ca/Journal/2000/win00/acid.html Almanac of Policy Issues. *What is Acid Rain and What Causes it?* Available: http://www.policyalmanac.org/environment/archive/acid_rain.shtml

	Brainstorm ways to counteract the weathering effects caused by acid rain. Materials: rainwater with a pH of 4, various rocks such as limestone, granite, basalt. Calculate the amount of limestone necessary to counteract the effects of the acid rain. Mechanical weathering materials per lab group: rock chips, hand lens, two plastic containers with lids, water, 50 mL beaker, mortar and pestle ***Journal Write:*** Has weathering occurred? Use data from your investigation to support your answer. Have mechanical and chemical lab groups share their results. Read to be informed about mechanical and chemical weathering. Glencoe McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment, and the Universe. pp. 153-161. Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 37-40. GSFC/GLOBE. *Soil Forming Factors.* Available: http://ltpwww.gsfc.nasa.gov/globe/soilform/weather.htm Or other similar text passages may be used. INTEREST CENTER Penn State. EMS. *Effects of Acid Rain.*

	Available: http://www.ems.psu.edu/info/explore/acidr/effects.htm US EPA. *The Effects of Acid Rain on Automotive Coatings.* Available: http://www.epa.gov/airmarkets/acidrain/effects/carcoatings.html US EPA. *The Effects of Acid Rain: Materials.* Available: http://www.epa.gov/airmarkets/acidrain/effects/materials.html
EVALUATE	***Journal Write***: Create a concept map that compares mechanical and chemical weathering. Support your answer using evidence from your laboratory simulation.

Materials per lab group:

- Sand sample
- Stereomicroscope
- Hand lens
- Vial and lid
- Glue
- Black construction paper 4cm x 4cm
- Four toothpicks
- 50 g limestone chips
- Mortar
- Pestle
- Weak acid
- Two plastic containers with lid
- Rock chips
- One beaker 50 mL

- Two beakers 400 mL

Teacher

- Granite
- Basalt

What Minerals are in Your Sand?

Materials per lab group: hand lens or stereoscope, 4cm x 4cm square of black paper, toothpicks, sand

Directions:

1. Design a data table to record the minerals present in the sand sample.
2. Pour a about a teaspoon of sand onto the black paper.
3. Using the hand lens or stereoscope sort the grains according to color.
4. Examine individual sand grains. Observe their color, shape and texture.
5. Identify the sand grain by matching the type of sand grain to one of the descriptions.
6. Glue the sand grains on to data table.

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Mineral Name	Description	Mineral Name	Description
Basalt	Dull, black, gray or brownish red colored grains of gravel and sand	Mica	Shiny, paper thin, flexible sheets; light colored or white, translucent
Feldspar	Clear, yellow or pink squarish crystals with smooth, glossy or pearly luster	Olivine	Shiny crystal in various shades of green. May be transparent or translucent. Often found in basalt.
Garnet	Usually amber colored, but may be light pink. Look for diamond-shaped grain with twelve faces.	Quartz	Clear or transparent grains like small pieces of broken glass.
Granite	Light-colored to pink with salt and pepper pattern made up of inter-grown mineral crystals all about the same size.	Obsidian	Black, shiny glass particles made when lava cools rapidly
Magnetite	A black crystal looks like a double pyramid. An iron ore that is shiny like a metal and attracted to a magnet.		

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Lesson 5: FACTORS AFFECTING EROSION

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.3 The student will formulate a working hypothesis.

1.2.5 The student will select appropriate instruments and materials to conduct an investigation.

1.4.3 The student will use experimental data from various investigators to validate results.

1.7.5 The student will investigate career possibilities in the various areas of science.

Indicator(s): Core Learning Goal 2

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) -Destructive processes (weathering, erosion, subsidence, melting) Landform change (surface & groundwater, coasts, glacial processes, desert processes)

Student Outcome(s):

1. The student will be able to compare agents of erosion by designing a laboratory investigation.
2. The student will be able to describe the effects of different types of erosion by analyzing changes in the Louisiana coastline.

Brief Description:

In this lesson, the agents of erosion are reviewed. Focusing on one type of erosion, students design an experiment to determine factors that affect the rate of erosion. Students also explore changes in coastal landforms caused by massive erosional events like hurricanes.

Background knowledge / teacher notes:

After weathering, fragments of soil are carried away. Erosion is the process of transporting fragments produced by weathering. Agents of erosion include wind, waves, glaciers, and rivers. Long-term erosion can reshape the landscape forming features that can be seen on topographic maps. Pikes Peak, the Appalachian Mountains, and mesas are all land features that have been modified by weathering and erosion.

Lesson Description:

ENGAGE	Materials per lab group: 200 mL sand, 250 mL beaker, (dissecting) tray Directions: 1. Arrange the tray that the shorter side is in front of you. 2. Pour the sand into the tray on the side closest to you. 3. Transport the sand from one end of the tray to the other using as many different methods as you can. Discussion: 1. Record the methods used on the board or overhead. *blowing, pushing, tipping the pan, etc.* 2. What process are you demonstrating? *Erosion and deposition* 3. What forces in nature moves sediment? *Wind, water: rivers, waves, glaciers* 4. Are these constructive or destructive processes? *Erosion is destructive, but deposition is constructive*
EXPLORE	Materials per lab group: 200 mL sand, pebbles or gravel, small rocks, dissecting tray, four 250 mL beakers, ruler, water, straw or tubing Directions: 1. As a group, brainstorm factors that affect the rate of erosion by running water. Possible factors: *Amount of water, speed of flow, size of particles, composition of rock, amount or shape of sediment* 2. Select one factor to investigate. <u>Adaptive Strategy</u>: Brainstorm factors with the class. Work with

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	individual groups to develop procedures. ***Journal Write:*** 3. Write a hypothesis about the effect of that factor on the rate of erosion. 4. Design an experiment to test your hypothesis. 5. Create a data table to record the results.
EXPLAIN	Each group shares the factor they chose, a brief overview of their experiment, and their results with the class.
EXTEND	Technology Connection: Explore the effect of large-scale erosional events. Materials per lab group: magic marker, road map of Louisiana, and map of Louisiana coast. World Sites Atlas. *Road map of Louisiana* Available: http://www.sitesatlas.com/Maps/Maps/LA1.htm Louisiana Energy & Environmental Resource & Information Center. Louisiana State University. *Map of Louisiana Coast.* Available: http://www.leeric.lsu.edu/educat/lessons/erosion/la_coast.htm Directions: 1. Follow the instructions on Session II. Record your answers in your journal. Louisiana Energy & Environmental Resource & Information Center. Louisiana State University. *Louisiana Coastal Erosion Session II.* Available: http://www.leeric.lsu.edu/educat/lessons/erosion/coast_e2.htm G/T/ Technology Connection: Do sessions II and III

	Louisiana Energy & Environmental Resource & Information Center. Louisiana State University. *Louisiana Coastal Erosion Session II.* Available: http://www.leeric.lsu.edu/educat/lessons/erosion/coast_e2.htm INTEREST CENTER NASA. EOS. DAAC Study: *When the Dust Settles.* Available: http://earthobservatory.nasa.gov/Study/Dust/ Career Connection: Read about the work of Dr. Leal Mertes an associate professor of geography at the University of California at Santa Barbara and a co-investigator on the NASA-supported Global River Flood Studies team NASA. EOS. *Sedimental Reasons.* http://earthobservatory.nasa.gov/Study/FloydSediment/sediment.html
EVALUATE	***Journal Write:*** Design "before" and "after" maps of the Louisiana coast that show changes caused by erosion. Use captions to explain important features of your maps. Be sure to tell which agents of erosion were responsible for these changes.

Materials per lab group:

- Dissecting tray
- 200 mL sand
- 250 mL beaker

Running water erosion materials

- 200 mL sand
- Pebbles or gravel

- Small rocks
- Water
- Dissecting tray
- Four 250 mL beakers
- Ruler
- Straw or tubing

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Lesson 6: GROUNDWATER, AQUIFERS, AND LAND SUBSIDENCE

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.1.1 The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.

1.6.1 The student will use ratio and proportion in appropriate situations to solve problems.

1.7.1 The student will apply the skills, processes, and concepts of biology, chemistry, physics, and earth science to societal issues.

Indicator(s): Core Learning Goal 2

2.4.2 The student will explain how the transfer of energy drives the rock cycle. Assessment limits (at least) - Destructive processes (weathering, erosion, subsidence, melting) Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition) Landform change (surface & groundwater, coasts, glacial processes, desert processes)

Student Outcome(s):

1. The student will be able to determine factors that affect the location of groundwater by conducting a laboratory investigation.
2. The student will be able to describe relationships among ground water, land subsidence, and aquifers by reading a technical selection and observing the effects of chemical weathering.

Brief Description:

Students investigate conditions that lead to the formation of ground water. Students simulate removal of groundwater by constructing a model well. Then they explore the role of chemical weathering in the formation of caves, sinkholes and other karst topography. They derive the relationship among ground water, aquifer use and land subsidence by observing the formation and collapse of caves.

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Background knowledge / teacher notes:

Water that does not runoff into streams and rivers percolates down into the soil until it reaches an impermeable layer. It fills the pore spaces in between rocks forming groundwater. How much water is present in the ground depends on the porosity and permeability of the soil. Porosity refers to amount of open space present in the soil. Permeability is the rate at which water can pass through the soil. When we use well water, we are accessing groundwater. But plants can pull water upward from the water table into the open spaces through capillary action. Capillarity refers to the rate at which this water is pulled upward. Soils with large pore spaces have high permeability and low capillarity.

Most caves form in rocks that are easily dissolved by a weak natural acid (usually carbonic acid). This acid forms when rainwater mixes with carbon dioxide in the upper layers of the soil. All the caves in Missouri are of this type. With more than 5500 known caves, Missouri is known as the "cave state".

The formation of groundwater can also lead to the formation of caves. Most caves form as the water that percolates through the soil becomes acidic. Water mixed with carbon dioxide forms a weak carbonic acid solution that dissolves the soluble rocks. Soluble rocks include limestone, dolomite, gypsum, and marble. Caves formed in rocks are called solutional caves.

About 90% of solutional caves, both branchwork and maze, form as water moves from overlying recharge areas to springs in nearby valleys. The cavities forming below grow larger and join creating an underground river as part of a spring system. Water hollows out and enlarges the passages as it enters this system (often through sinkholes), moves below ground, and surfaces at a spring. Finally, in response to surface rivers eroding ever deeper, the subsurface water drains away…leaving behind a cave. Often the draining is incomplete, and a stream still flows through part of the cave.

Springs are the drainage points for caves: caves are really drained spring systems. A large spring, such as Big Spring near Van Buren, discharges millions of gallons per day and each 1000 gallons contains about one pound of dissolved rock. Indian Spring, which flows from Fantastic Caverns, discharges 9000 gallons per minute during peak flow.

The movement of rainwater down from the surface and through a cave shows the surface-subsurface connection. Karst, the dissolving of soluble rocks - limestone, dolomite, gypsum, or marble - plays a major role in land erosion. Karst areas have caves, springs, sinkholes and sinking streams (which flow into the ground and disappear) - making the whole area resemble Swiss cheese coated with soil.

There are two basic ways in which water from the surface recharges groundwater in Karst areas: discrete recharge and diffuse recharge. Discrete recharge is very localized, and often involves large quantities of water that move rapidly into groundwater supplies. A storm water stream disappearing into a sinkhole is an example. Discrete recharge typically provides ineffective natural filtration and cleansing for water. In contrast, diffuse recharge involves slower moving water that seeps through soil and rock units in route to groundwater supplies.

Understanding sinkholes is another way to understand the surface-subsurface relationship in cave country. A sinkhole is a depression in the earth's surface with subsurface drainage, where water has dissolved out a drainage network through the rock. Sinkholes are the entry points for water into spring systems. To trace the movement of underground water, a harmless dye (such as fluorescein) is poured into water flowing into a sinkhole. Charcoal packets placed at springs can remove some of the dye from the water. If the dye is detected, then that sinkhole is one of the sources for that spring.

Reprinted courtesy of *Fantastic Caverns*.
Available: http://www.fantastic-caverns.com/research.htm

"Land subsidence is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials. Subsidence is a global problem and, in the United States, more than 17,000 square miles in 45 States, an area roughly the size of New Hampshire and Vermont combined, have been directly affected by subsidence. The principal causes are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost. More than 80 percent of the identified subsidence in the nation is a consequence of our exploitation of underground water, and the increasing development of land and water resources threatens to exacerbate existing land-subsidence problems and initiate new ones. In many areas of the arid Southwest, and in more humid areas underlain by soluble rocks such as limestone, gypsum, or salt, land subsidence is an often- overlooked environmental consequence of our land- and water- use practices."

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From USGS. Science for a Changing World. *USGS Ground Water Information Page Land Subsidence.*

Available: http://water.usgs.gov/ogw/subsidence.html

Lesson Description:

ENGAGE	Discussion: 1. Where does the water that we use come from? *Northern Anne Arundel uses public water stored in reservoirs. Other areas get their water from wells.* 2. Where does well water come from? *ground water.* Read to be informed about ground water. USGS. Water Science For Schools. *Earth's Water-Ground Water.* Available: http://ga.water.usgs.gov/edu/earthgw.html USGS. Water Science For Schools. *Ground-water aquifers.* Available: http://ga.water.usgs.gov/edu/earthgwaquifer.html Or Windows to the Universe. *Groundwater.* Available: http://windows.arc.nasa.gov/cgi-bin/tour.cgi?link=/earth/Water/groundwater.html&art=ok&cdp=/windows3.html&cd=false&frp=/windows3.html&fr=f&sw=false&edu=mid For information on aquifers, click on the underlined word. Discussion questions: 1. What is ground water? 2. How can we find ground water? 3. How important is ground water? 4. What is an aquifer and how do they work? Picture of artesian well.

	USGS. Water Science For Schools. *The Water Science Picture Gallery.* Available: http://ga.water.usgs.gov/edu/mearthgw.html Optional Activity: Learn about the parts of an aquifer and how they work by building an edible aquifer. Materials: blue or red food coloring, vanilla ice cream, clear soda pop, small gummy bears, gummy pieces or crushed ice, variety of colored cake decoration sprinkles and sugars, drinking straws, clear plastic cups, spoons Directions: 1. Fill a clear plastic cup 1/3 full with gummy bears, gummy pieces, or crushed ice. 2. Add enough soda to just cover the candy/ice. 3. Add a layer of ice cream over the water-filled aquifer. 4. Add more crushed ice on top. 5. Sprinkle colored sugars or sprinkles over the top ***Journal Write***: 6. What do the layers represent? *ice cream- impermeable layer crushed ice- gravel and soils, soda- ground water* 7. Draw and label a diagram of your aquifer. 8. How can you access the ground water/soda? 9. Using a straw, drill a well into the center of your aquifer. 10. Slowly begin to pump the well by sucking on the straw. 11. Record your observations. *A dip is formed around the well. Water table declines.* 12. Why do wells sometimes run dry? 13. Now add the food coloring or Kool Aid to the top layer. 14. Make it "rain" by pouring soda over the food coloring. 15. What does the food coloring represent? *contamination.*

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	16. What happens to the ground water/soda? *Rain showers recharge aquifers, but contamination entered too.* From Groundwater Foundation. *Cool Groundwater Activity*. Available: http://www.groundwater.org/KidsCorner/activity.htm
EXPLORE	Discussion: What conditions are necessary to form ground water? *Soil must be porous (spaces between soil particles), permeable (allow water to move through the soil particles), have a way to trap or hold the water, and a way to carry the water to the surface (capillary action)* Teacher Demonstration on porosity and permeability: Materials: one graduated cylinder (100 mL works well), 50 mL of coarse sand soil sample, one 100 mL beaker, stop watch 1. Design a data table on the board or overhead. 2. Fill the graduated cylinder half full (50 mL) with the soil sample. Do not pack. *50 mL is the original volume of the sediment including pore spaces.* 3. Pour water (50 mL) into the container. *50 mL is the original volume of the sediment.* 4. Time how long it takes the water to reach the bottom. *This is the permeability of the sample.* 5. When the entire soil sample is wet, tap the graduated cylinder to remove any air bubbles in the soil. 6. Read the water level. Be as accurate as possible. *This is the volume of the water and sediment without any pore spaces.* 7. Record this measurement in the data table. 8. Calculate porosity: Record the following calculations on the board or overhead. · Subtract the volume of water and sediment from the starting volume of sediment and water (50 + 50 =100 mL)

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	· *This is the volume of the pore spaces*. Record this on the data table. · Divide the volume of the pore spaces by the volume of the original sediment plus pore space (50 mL) and multiply by 100. · Record the porosity of the soil sample in the data table. Based on Heath. (1999). <u>Earth Science Laboratory Investigations</u>. Chapter 9A Porosity, Permeability, and Capillarity. pp. 43-46. ***Journal Write***: 1. Write a hypothesis about how the porosity and permeability of the soil affects the location of ground water. 2. Using the teacher demonstration as a model, design an investigation to determine the effect of porosity and permeability on two different soil samples. Materials per lab group: two graduated cylinders (100 mL works well), 50 mL of each soil sample: medium sand, fine sand, two 100 mL beaker, two stop watch 3. Design a data table to record the results and calculations. 4. Conduct the investigation. <u>Adaptive Strategy</u>: Have each lab group test only one sample and then share results. Allow students to use calculators. <u>G/T Connection</u>: Compare capillarity of soil samples. Materials per G/T group: two beakers, hollow clear tube, ring stand, clamp, two sand samples, ruler, marking pencil, filter paper, rubber band. General procedure: 1. Using the marking pencil and ruler, measure in 4 cm from the end of the tube and draw a line. 2. Use the same end; cover the open end of the tube with filter

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	paper. Use the rubber band or tape to hold it in place. 3. Fill the tube with sand samples (to a depth of 10 cm if possible). 4. Clamp to ring stand. 5. Fill beaker with water and place below tube. 6. Place the end of the tube in the water, just below the surface. 7. Time how long it takes water to reach the 4 cm line. This is the capillarity of the sample. 8. Repeat with different sample. Based on Heath. (1999). Earth Science Laboratory Investigations. Chapter 9A Porosity, Permeability, and Capillarity. pp. 43-46.
EXPLAIN	***Journal Write:*** 1. What factors affect the rate at which various soils absorb water? 2. What is the relationship between porosity and permeability? *Higher porosity increases permeability and decreases capillarity.*
EXTEND	Show pictures of solution formed topography: South China Karst (figure KL-1.3 from Geomorphology from space CD), Caves, and Sinkholes. NASA.JPL. *Geomorphology From Space. Chapter 7 Karst Landforms and Lakes.* Available: http://daac.gsfc.nasa.gov/DAAC_DOCS/geomorphology/GEO_7/GEO_PLATE_KL-1.HTML Also available as a CD. Terra Galleria Photography. *Carlsbad Caverns National Park.* Available: http://www.terragalleria.com/parks/np.carlsbad-caverns.html USGS. Water Science For Schools. *Sinkholes.*

	Available: http://wwwga.usgs.gov/edu/earthgwsinkholes.html USGS. Science for a changing world. *Geologic hazard team. Sinkhole at Winter Park Florida.* Available: http://landslides.usgs.gov/html_files/landslides/slides/slide10.htm This sinkhole occurred in 1981, in the time span of one day. The city of Winter Park stabilized and sealed the sinkhole, converting it into an urban lake. Brainstorm how these features were formed. *These are solution-derived land features form from differential chemical and mechanical erosion by water on soluble rock, such as limestone, dolomite, gypsum, or salt, at or near Earth's surface. Sinkholes, towers, or caves, and a complex subsurface drainage system characterize these landforms. Climate plays a major part in the formation of these landforms. These features form best on thick, fractured, and pure limestone in a humid environment in which the subsurface and surface are being modified simultaneously. Karst topography is common in Florida, Kentucky, Missouri, Pennsylvania, and Tennessee as well as other places in the world such as South China.* Set up the following teacher demonstration. Teacher Demonstration: Materials: clear container (if possible with a drain and stopper), limestone chips, sand, gravel, clay mixture, vinegar or carbonic acid Directions: 1. Fill one half of a clear container with crushed limestone several centimeters deep.

	2. Fill the other half of the container to the same level with sand. 3. Cover the surface with a mixture of sand gravel and clay. 4. Slowly pour a weak acid (vinegar or carbonic acid) over the entire surface. 5. Wait several minutes. While waiting for the cave to form, students read about solution formed landforms. Glencoe McGraw-Hill. (2002). <u>Glencoe Earth Science: Geology, the Environment, and the Universe</u>. pp. 244-247. Prentice Hall. (2002). <u>Lutgens & Tarbuck Foundations of Earth Science</u>. pp. 82-84. Or other similar text passages. Discussion: 1. Make observations from the top and sides of the container. 2. What feature(s) have formed? *Cave* 3. Describe how was this feature formed. 4. Predict what will happen if the water in the cave were removed. *The weight of the overlying ground becomes too great, or if the dissolved area becomes too large, the surface collapses into the cave. This is an example of Subsidence.* 5. *If your container has a drain, remove the stopper and allow the water to drain. Subsidence will occur.* 6. What natural occurrence would cause this to happen? *Drought. Sinkholes appeared in Winter Park, Fla. after a two-year drought.* Read to be informed about land subsidence. USGS. Science for a Changing World. *Ground Water Resources for*

	the Future. Land Subsidence in the United States. Available: http://water.usgs.gov/ogw/pubs/fs00165/ USGS Fact Sheet-165-00 Adaptive Strategy: USGS. Water Science for Schools. *Land Subsidence.* Available: http://ga.water.usgs.gov/edu/earthgwlandsubside.html Be sure to click on sinkholes and suffered damage to read the complete article. ***Journal Write:*** 1. What is land subsidence? 2. What are the causes and effects of land subsidence? Discussion: How should we prevent land subsidence? INTEREST CENTER National Park Service. *Mammoth Cave National Park.* Available: http://www.nps.gov/maca/home.htm Good Earth Graphics. *The US Show Caves Directory.* Available: http://www.goodearthgraphics.com/showcave.html Good Earth Graphics. *The Virtual Cave.* Available: http://www.goodearthgraphics.com/virtcave.html
EVALUATE	***Journal Write:*** Describe the relationship among ground water, aquifers and land subsidence?

Materials per lab group:

Soil Investigation supplies

- Coarse sand, medium sand, fine sand
- Two 100 mL graduated cylinders
- Two 400 mL beakers
- Timer
- Filter paper
- Grease pencil
- Masking tape
- Ruler
- Glass or plastic tube (1 cm x 15 cm)
- Ring stand
- Crushed limestone
- Sand
- Gravel
- Weak acid
- Small clear plastic terrarium or shoebox
- Clay
- Sugar
- Water

Aquifer supplies

- Blue or red food coloring or Kool Aid
- Vanilla ice cream
- Clear soda pop
- Crushed ice
- Variety of colored cake decoration sprinkles and sugars
- Drinking straws
- Clear plastic cups

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Lesson 7: COASTAL LANDFORMS

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.1.1 The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

Indicator(s): Core Learning Goal 2

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) -Destructive processes (weathering, erosion, subsidence, melting) Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition) Landform change (surface & groundwater, coasts, glacial processes, desert processes)

Student Outcome(s):

1. The student will be able to explain the formation of coastal landforms by investigating the effects of wave erosion and deposition on the shoreline.
2. The student will be able to describe the impact of stabilizing the shoreline by performing a laboratory investigation.

Brief Description:

The interaction among wave erosion, longshore transport, and deposition forms most coastal landforms. Through laboratory investigations, students observe the effect of waves and longshore transport on the shape of a shoreline. They explore how humans have attempted to stabilize the coastline and the consequences of interrupting longshore transport.

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Background knowledge/teacher notes:

The shape of a shoreline is the result of interactions among wind, waves, and the longshore current. Most waves reach the shore at an angle causing the outgoing water to leave the beach at an angle. Some water is trapped and pushed down the beach, generating a longshore current. The longshore current runs parallel to the beach and in the same direction as the waves. This current causes people, toys and sand to move down the beach, generally from north to south. The stronger the waves are, the stronger the longshore current.

If groins or jetties interrupt the longshore current, the water and sand piles up on the northern side creating a spit. (Groin - A wall of concrete, rock, wood, or sandbags built perpendicular to the coastline for the purpose of trapping the moving sand and creating a wider beach. Jetty - A pair of long groins that protect a harbor channel from sedimentation). Once enough water has piled up, it moves quickly around the impediment and continues on. This results in erosion on the southern side of the groin or jetty. Ocean City and Assateague are good examples of this phenomenon.

Lesson Description:

ENGAGE	Discussion: 1. Show students a [illegible] Maryland's coastline. University of Va. *C[illegible]ake Bay map.* Available: http://www.virginia.edu/~envneg/Chesapeake%20Bay.jpe 2. What do you notice about the shape of the coastline? *It's relatively straight, smooth…* 3. Why aren't there any large pieces of land that jut out into the ocean? *Waves must erode the land* 4. How do waves affect the shoreline? Simple simulation: Teacher Directions: 1. Arrange eight desks into a point of land or headland. 2. Have the students line up perpendicular to the desks and link

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	arms. 3. They represent a wave. 4. Waves move until they hit an object, usually the shoreline. 5. Have students walk forward and keep walking until the hit the shoreline. 6. Have the class observe what happens. *Wave will fold around the point.* 7. What happened to the energy in the wave? *Expended on the shoreline causing erosion* 8. What will happen to the headland over time? *Eroded away* 9. Repeat the process with the desks arranged into a semicircle, a bay. Make sure the line of students extends out over both sides of the semicircle. *In this case, the ends of the wave hit the headlands and the center of the wave diverge, energy is spread out over a larger area. Sediment eroded from the headlands is deposited and over time the bays fill in.* Adaptive Strategy: Help students interpret the effect of waves. Show them a diagram of waves interacting with shoreline and the resulting erosion of headlands. Pictures and diagram available at North Arizona University Web. *Shorelines.* Available: http://jan.ucc.nau.edu/~wittke/GLG100/Shoreline.html
EXPLORE	Teacher Note: Be sure students save their beach set up. Working in groups of two, students investigate the impact of waves and offshore currents on beaches Materials per lab group: 200 mL sand, two 250 mL beakers, dissecting tray, three small wooden blocks, water, spoon Directions: 1. Build a beach along part of one side of the tray. Beach should be about two centimeters high.

	2. Gently add water until _ of the beach is covered. 3. Moving the small block up and down, generate waves. <u>Adaptive Strategy</u>: Focus the student's attention on the length of the beach. Based on Holt, Rinehart, and Winston. (1998) <u>Modern Earth Science, In-depth Investigations.</u> Investigation 16 *Beaches*. pp. 77-80.
EXPLAIN	***Journal Write:*** 1. What impact did the waves have on the beach? *Erodes it depositing some of the sand off shore.* 2. How did the shape of the beach change? *It becomes thinner and longer.* 3. Predict what will happen if no sand is added to the beach.
EXTEND	Discussion: 1. What is a barrier island? 2. Where do they come from? Howstuffworks. *How Barrier Islands Work*. *What are Barrier Islands?* Available: http://www.howstuffworks.com/barrier-island.htm Has a picture of a barrier island. <u>Adaptive Strategy</u>: Students read the short article on barrier islands. Tell the students the history of the Ocean City Inlet. Show the picture of the Inlet (See resources). *Ocean City, which is located at the southern end of Fenwick Island along Maryland's eastern shore, has been a popular beach resort for a long time. In the 1920s, several large hotels were built there, and by the 1950s, development boomed*

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	dramatically and lasted almost 30 years. In the 1970s, ecological concerns about the island were raised, and laws were enacted to halt dredging of channels and filling in wetlands. *A hurricane opened the Ocean City Inlet in 1933 (the inlet separates Fenwick Island from Assateague Island to the south). To keep the channel navigable to the mainland, the U.S. Army Corps of Engineers constructed two rock jetties.* From Howstuffworks. *How Barrier Islands Work. Changing the Shifting Sands.* Available: http://www.howstuffworks.com/barrier-island4.htm 1. Predict what affect the jetty/block will have on the movement of sand. 2. Add a block to the end of the beach. 3. Draw a picture of the beach with the groin/jetty 4. Continue generating the waves for several minutes. ***Journal Write:*** 5. Draw a picture of the beach. 6. What impact did the groin/jetty have on the beach? *Sand was deposited on the upper side of the jetty and eroded away on the lower side.* Read to be informed about the formation coastal landforms. Glencoe-McGraw-Hill. (2002). <u>Glencoe Earth Science Geology, the Environment and the Universe</u>. pp. 417-418. Prentice-Hall. (2002). <u>Lutgens & Tarbuck Foundations of Earth Science</u>. pp. 259-260. ***Journal Write:*** 1. Draw a picture of the coast. Label the coastal landforms: spit, beach, barrier island, bay mouth bar, lagoon, tombolo.

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	2. Explain how the interaction among wave erosion, deposition and longshore transport form coastal features. Discussion: View images of a spit and how groins/jetties affected a beach. Carolina Coastal Science. *Inquiry Images.* Available: http://www.ncsu.edu/coast/inquiry/inquiry3/ View pictures of the Ocean City Inlet and Assateague. (See resources) Howstuffworks. *How Barrier Islands Work. Changing the Shifting Sands.* Available: http://www.howstuffworks.com/barrier-island4.htm 1. Why is Assateague no longer lined up with Ocean City? 2. Predict the fate of Assateague Island. INTEREST CENTER Good Earth Graphics. *The Virtual Cave. Sea Caves.* Available: http://www.goodearthgraphics.com/virtcave/seacaves/seacaves.html
EVALUATE	***Journal Write***: 1. How were coastal landforms such as spits, beaches and barrier islands formed? Use evidence from your laboratory investigation and reading to support your answer. 2. Are groins and jetties a good solution to stabilize the shoreline? Use evidence from your laboratory investigation and reading to support your answer.

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Materials per lab group:

- Dissecting tray
- Water
- Two 250 mL beakers
- Three small wooden blocks
- 200 mL sand
- Spoon

A hurricane opened the Ocean City Inlet in 1933 (the inlet separates Fenwick Island from Assateague Island to the south). To keep the channel navigable to the mainland, the U.S. Army Corps of Engineers constructed two rock jetties. Notice how Assateague's shoreline has been eroded.

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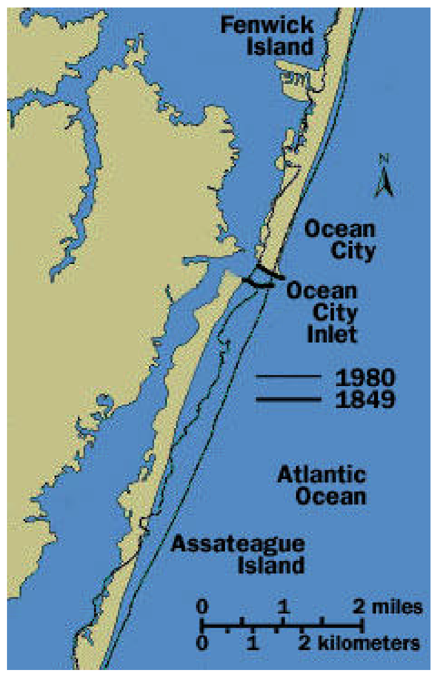
From Howstuffworks. *How Barrier Islands Work. Changing the Shifting Sands.* Available: http://www.howstuffworks.com/barrier-island4.htm



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Lesson 8: GLACIAL EROSION AND DEPOSITION

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

1.5.6 The student will read a technical selection and interpret it appropriately.

1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.

Indicator(s): Core Learning Goal 2

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) - Destructive processes (weathering, erosion, subsidence, melting) Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition) Landform change (surface & groundwater, coasts, glacial processes, desert processes)

Student Outcome(s):

1. The student will be able to describe how glaciers are formed and compare the two types of glaciers by reading a technical selection.
2. The student will be able to observe how glaciers are both agents of erosion and deposition by performing a simulation activity and examining land features formed in glacial areas.

Brief Description:

What are glaciers? How are they formed? How do they affect the landscape? Students explore these questions and examine glaciers as agents of erosion and deposition.

Background knowledge / teacher notes:

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Teacher Note: Make the blocks of ice the night before. Fill plastic containers (disposable plastic containers by Glad) with water and freeze. Make sure the blocks of ice will fit inside the paint tray.

A glacier is a dynamic system consisting of snow, ice and often rock debris, that transports material from higher elevations, where snow accumulates, to lower elevations, where snow and ice melt. Snow becomes glacier ice over time when the pressure of increasing layers of snow, accumulating year after year during an ice age, transforms the snow, first into firn, which is very dense snow, and eventually into ice.
Reprinted from narrated script written by NASA glaciologist Dorothy Hall for the NASA video *Glacier Bay, Alaska, from the Ground, Air and Space***.**
Available: http://sdcd.gsfc.nasa.gov/GLACIER.BAY/glacierbay.script.html

The effect of the moving glacier is to scour and grind the bedrock surface over which it travels as it advances, and then to redeposit vast quantities of sand, gravel and silt as it retreats. Further advances and retreats of subsequent ice sheets continue to rework these accumulated glacial sediments.
The effects of glaciation can be seen everywhere in Vermont. Since Vermont was completely overridden by successive ice sheets, no portion of the state escaped. In the higher mountain regions, such as here atop Mt. Hunger or on the summit of towering Mt. Mansfield, there are glacial polish, striations, roches moutonnees (plucking on the backside of mountains and ridges) and an occasional perched erratic boulder. In the valleys and lowlands there are sand and gravel deposits from ancient river beds and deltas, near-ice deposits like moraines, kames, eskers and kettle holes, and the extensive clays and silts and yearly varves that accumulated at the bottoms of ancient glacial lakes.
Reprinted with permission from Wesley Alan Wright.
University of Vermont. *What are the Physical Effects of Glaciers?*
Available: http://www.uvm.edu/whale//GlaciersPhysicalEffect.html

Lesson Description:

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ENGAGE	Discussion: 1. What percent of the earth's water is fresh water? *3%* 2. Of that 3% how much is available for our use? *1%* 3. What happened to the other 2 %? *Locked in glaciers and ice sheets.* Show pictures of glaciers. NASA. *Glacier Galleries: Mighty Glaciers.* Available: http://sdcd.gsfc.nasa.gov/GLACIER.BAY/pictures.glaciers.html 4. What is a glacier?
EXPLORE	Read to be informed about how glaciers form and the two types of glaciers: valley and continental. Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment, and the Universe. pp. 198-201. Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 90-93. Or other similar text passages. ***Journal Write:*** Create a graphic organizer to compare the two types of glaciers. Adaptive Strategy: Review basic information about how glaciers are formed using this ThinkQuest reading. ThinkQuestJunior. *Glaciers.* Available: http://tqjunior.advanced.org/3876/glaciers.html
EXPLAIN	***Journal Write:*** 1. What is a glacier? 2. How do they form? *Snow becomes glacier ice over time when the pressure of increasing layers of snow, accumulating year after year during an ice age, transforms the snow, first into firn, which is very dense snow, and eventually into ice.*

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	3. Compare the continental and valley glaciers. *Valley glaciers for in valleys. When the weight of the glacier becomes to heavy, it begins to flow down the mountain. This movement can cause deep cracks called crevasses to form. Continental glaciers or ice sheets are much larger than valley glaciers. They are also thickest at the center causing the glacier to flatten and spread out in all directions.*
EXTEND	In small groups discuss how glaciers might affect land features. Investigate the impact of glaciers on the landscape. Materials per lab group: large block of ice, mixture of sand, gravel and small rocks, clay, paint tray Directions: 1. A large block of ice will act as a glacier. 2. Cover the paint tray with clay. 3. Remember that glaciers move very slowly and often advance and retreat many times. Start at the top of the tray and slowly, but firmly push the block of ice to the lower end of the tray and then back up. ***Journal Write:*** 4. How has the surface of the clay changed? 5. Examine the bottom of the glacier. 6. How has the glacier changed? 7. Form a “mountain” on the top of the paint tray using the mixture of sediments. 8. Place your glacier on the mountain. Starting on the mountain slowly, but firmly push the block of ice to the lower end of the tray and then back up. ***Journal Write:***

	9. How has the surface of the clay changed? 10. Examine the bottom of the glacier. 11. How has the glacier changed? 12. How has the mountain changed? 13. What happened to the mountain sediments? Class discussion: 1. How do glaciers affect the land features? *They erode some areas and form deposits on others.* 2. What land features do glaciers form? *U-shaped valleys, moraines, outwash plain, drumlins, eskers, kettle hole, lakes* 3. Classify the landforms as those made by glacial erosion and those made by glacial deposition. ***Journal Write:*** 4. Illustrate the features and label. 5. Which features were formed by erosion and which were formed by deposition? 6. View land features formed by glacial erosion and deposition. Teacher Note: The website *Landforms Created by Glacial Erosion* offers a few pictures with explanations. If you feel comfortable and would like to discuss other features, the website *Glaciers Parts 1 and 2* have a large variety of pictures with labels, but no explanation. *Landforms Created by Glacial Erosion.* Available: http://www.dc.peachnet.edu/~pgore/students/w97/landry/ Duke University. Nicholas School of the Environment and Earth Sciences. *Glaciers Part 1.* Available: http://www.geo.duke.edu/geo41/gla1.htm

	Duke University. Nicholas School of the Environment and Earth Sciences. *Glaciers Part 2.* Available: http://www.geo.duke.edu/geo41/gla2.htm G/T Connection: Examine the effects of glacial erosion. University of Cincinnati**.** Glacial Geology at UC. *Glacial Erosion Pictures*. Available: http://tvl1.geo.uc.edu/ice/Image/eropro/eropro.html Select one or two areas under each category: abrasion, mixed and quarrying. (Most of the pictures under Abrasion and Mixed have questions to guide the students in their analysis.) Use the questions as a guide and discuss how these features were formed.
EVALUATE	***Journal Write***: In a brief paragraph, compare the two types of glaciers. Explain how glaciers act as agents of erosion and deposition. Cite evidence form your reading and from your simulation activity.

Materials per lab group:

- Block of ice
- Clay, enough to cover the paint tray
- Sand and gravel mixture
- Paint tray
- Beaker

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Lesson 9: WIND EROSION AND DESERTIFICATION

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.7.1 The student will apply the skills, processes, and concepts of biology, chemistry, physics, and earth science to societal issues.

1.7.2 The student will identify and evaluate the impact of scientific ideas and/or advancements in technology on society.

Indicator(s): Core Learning Goal 2

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) -Destructive processes (weathering, erosion, subsidence, melting) Landform change (surface & groundwater, coasts, glacial processes, desert processes)

Student Outcome(s):

The student will be able to describe the causes and effects of desertification by analyzing the impact of wind erosion and human activities on the soil.

Brief Description:

Students gain an historical perspective about the relationship between land management practices, weather, economics, and erosion. (This is particularly evident when researching the Dust Bowl in light of the Great Depression.) Human actions can have major consequences that change soil characteristics and lead to desertification.

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Background knowledge / teacher notes:

During the last 40 years alone, almost a third of the world's topsoil has been lost to erosion.
A good example of this is the Dust Bowl disaster. The Dust Bowl disaster occurred in the southwestern Great Plains region of the United States in the 1930's, including parts of Kansas, Oklahoma, Texas, New Mexico, and Colorado. Years of poor farming techniques left the land open to the ravages of wind.
Could this area become a desert? Deserts are areas where precipitation is less than 25 cm (~10") of precipitation per year or rainfall is insufficient to grow crops without irrigation. Regions such as Great Basin and the Upper and Lower Sonoran, Mohave, and Chihuahuan Deserts are especially vulnerable to loss of soil by wind erosion.
Eolian landforms are found in regions of Earth where erosion and deposition by wind are the dominant forces shaping the face of the landscape. Regions influenced by wind include most of the dry climates of Earth. This includes regions classified as arid deserts and semiarid steppe. Wind can also cause erosion and deposition in environments where sediments have been recently deposited or disturbed. Such environments include lake and ocean coastline beaches, alluvial fans, and farmland where topsoil has been disturbed by cultivation

Three different processes are responsible for the transport of sediment by wind. Wind erosion of surface particles begins when air velocities reach about 4.5 meters per second. A rolling motion called traction or creep (the later term should not to be confused with soil creep) characterizes this first movement of particles. In strong winds, particles as large as small pebbles can move through traction. About 20 to 25 percent of wind erosion is by traction. The second type of wind sediment transport involves particles being lifted off the ground, becoming suspended in the air, and then returning to the ground surface several centimeters downwind. This type of transport is called saltation, and this process accounts for 75 to 80 percent of the sediment transport in dry land environments. Saltating particles are also responsible for sending additional sediment into transport. When a falling particle strikes the ground surface, part of its force of impact is transferred to another particle causing it to become airborne. Small sized particles like silt and clay have the ability to be carried in suspension thousands of meters into the air and hundreds of kilometers downwind.

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When the force of wind is concentrated on a particular spot in the landscape, erosion can carve out a pit known as a deflation hollow. Deflation hollows range in size from a few meters to a hundred meters in diameter, and may develop over several days or a couple of seasons. Much larger depressions are also found in the arid regions throughout the world. These broad, shallow depressions, called pans, can cover thousands of square kilometers. One of the largest pans, known as the Qattara Depression is found in the Libyan Desert of Egypt. This pan covers around 15,000 square kilometers.

In some dry climate areas, persistent winds erode all sediments the size of sand and smaller leaving pebbles and larger particles on the ground surface. These surfaces are called desert pavement.

From Department of Geography. Okanagan University College. *Introduction to Geomorphology Eolian Processes and Landforms.*

Available: http://www.geog.ouc.bc.ca/physgeog/contents/11r.html

Lesson Description:

ENGAGE	Multicultural Connection: Listen to people describing the dust bowl. Library of Congress. American Memory Collection. *Voices from the Dust Bowl: The Charles L. Todd and Robert Sonkin Migrant Worker Collection. Interviews of Dust Storms in Oklahoma.* Available: http://lcweb2.loc.gov/ammem/afctshtml/tshome.html Discussion: 1. What was the “dust bowl?’ 2. What factors might have caused the dust bowl? *Drought and poor land use led to increased erosion.*
EXPLORE	Working in lab groups, design an experiment to investigate the factors that caused the dust bowl or use the sample procedures

	provided. Materials per lab group: sand mixture enough to cover the tray, hair dryer, dissecting tray, ruler, water, three 400 mL beakers, grass or steel wool, gloves Teacher Note: Make a mixture of 65% sand, 25% pebbles and 10% small rocks Sample procedures: The Effect of Wind Erosion Part One: 1. Cover the bottom of the tray with 1 cm of the sand mixture. ***Journal Write:*** 2. Draw a picture of the tray. 3. Turn the hair dryer on the lowest and coolest setting. 4. Blow air on the sand mixture at the front of the tray for several minutes. ***Journal Write:*** 5. Diagram or describe how the landscape is changing. 6. How has the depth of the soil changed? 7. Is erosion occurring? List evidence to support your answer. 8. Does the wind affect all particles equally? List evidence to support your answer. Part Two: 9. Remix the sand mixture and smooth out. 10. Simulate rain by pouring water over the sand. ***Journal Write:*** 11. Draw a picture of the tray. 12. Turn the hair dryer on the lowest and coolest setting. 13. Blow air on the sand mixture at the front of the tray for several minutes. ***Journal Write:*** 14. Diagram or describe how the landscape is changing.

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	15. How has the depth of the soil changed? 16. Is erosion occurring? List evidence to support your answer. Part Three: 17. Remix the moist sand mixture and smooth out. 18. Add vegetation or simulate vegetation (tease apart the steel wool partially bury in the sand). When handling steel wool, use gloves to prevent splinters. ***Journal Write:*** 19. Draw a picture of the tray. 20. Turn the hair dryer on the lowest and coolest setting. 21. Blow air on the sand mixture at the front of the tray for several minutes. ***Journal Write:*** 22. Diagram or describe how the landscape is changing. 23. How has the depth of the soil changed? 24. Is erosion occurring? List evidence to support your answer. G/T Connection: Part One is modified to include the study of sand dunes. 1. Cover the bottom of the tray with 1 cm of the sand mixture. ***Journal Write:*** 2. Draw a picture of the tray. 3. Turn the hair dryer on the lowest and coolest setting. 4. Blow air on the sand mixture at the front of the tray for a few seconds. 5. Observe the movement of particles. Hint: there are three types of movement ***Journal Write:*** 6. Which particles are moving? 7. Diagram or describe their movement.

	8. What is the relationship between particle size, weight and movement? *Particles that roll along are moved by creep. Smaller particles move by suspension. Larger particles move by saltation (bouncing).* 9. Continue blowing for several minutes. ***Journal Write:*** 10. How can you tell where the air is touching the sand? *Ripples form.* 11. Diagram or describe how the landscape is changing 12. Form a large sand dune across the center of the tray. 13. Continue blowing for several minutes. ***Journal Write:*** 14. Diagram the shape of the sand dunes. Indicate the direction of the wind. 15. Continue blowing for several minutes. 16. Diagram the shape of the sand dunes. Indicate the direction of the wind. 17. How has the shape of the dune changed? 18. Increase the strength of the wind. Continue blowing for several minutes. 19. Diagram the shape of the sand dunes. Indicate the direction of the wind. 20. How has the shape of the dune changed?
EXPLAIN	***Journal Write:*** 1. How does the depth of the soil change over time? 2. Some deserts are covered with large coarse sediments, a condition called desert pavement. Using your observations from the investigation, how does desert pavement form? 3. How does sand moisture affect rates of erosion? 4. How does vegetation affect rates of erosion?

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	Teacher Note: Pictures of desert pavements may be found at any of the following sites: Glencoe-McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. p. 192. University of Wisconsin. *Desert Pavement and Ripples.* Available: http://botit.botany.wisc.edu:16080/images/veg/Barrens/Desert_pavement_and_ripples_VK.html Arizona Desert Museum. *Soil Surfaces.* Available: http://www.desertmuseum.org/books/nhsd_surfaces.html
EXTEND	Read to be informed about the dust bowl and desertification. DustBowl History. *History of the Dustbowl*. Available: http://users.rcn.com/gregjonz/dust/dustbowl.html And ESO. DAAC Alliance. *From the Dust Bowl to the Sahel.* Available: http://earthobservatory.nasa.gov/Study/DustBowl/ Or other similar text passages. ***Journal Write:*** 1. Create a graphic organizer to record the causes and effects of desertification. 2. What can be done to prevent or reverse desertification? Multicultural Connection: Examine the following maps. Predict locations in the world where desertification is occurring or has a high probability of occurring. Use evidence from the maps to support your answer. Blue Planet Biomes. *World Climates.*

	Available: http://www.blueplanetbiomes.org/climate.htm NCRS. *World Source Resource Map Index. Wind Erosion Vulnerability.* Available: http://www.nrcs.usda.gov/technical/worldsoils/mapindx/eroswind.html Explore the effects of desertification in other parts of the world. UNCCD. *Fact Sheet 11. Consequences of Desertification in Africa.* Available: http://www.unccd.int/publicinfo/factsheets/showFS.php?number=11 UNCCD. *Fact Sheet 12. Consequences of Desertification in Asia.* Available http://www.unccd.int/publicinfo/factsheets/showFS.php?number=12 Could desertification happen in Maryland? Possible service learning project Directions: ***Journal Write:*** 1. Describe soils in Maryland. USDA.NRCS. *Sassafras – Maryland State Soil.* Available: http://soils.usda.gov/gallery/state/html_docs/md_soil.htm 2. Compare the water and wind erosion charts from 1992-2000. USDA.NRCS. *Total Water and Wind Erosion 1992.* Available: http://www.nrcs.usda.gov/technical/land/tables/t4037.html USDA.NRCS. *Total Water and Wind Erosion 1997.* Available: http://www.nrcs.usda.gov/technical/land/meta/m5112.html

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	3. Examine the vegetative index maps. Foreign Agriculture Production Service. *Mid-Atlantic States 1999 Drought. Vegetative Index Map July 20 to August 9, 1999.* Available: http://www.fas.usda.gov/pecad2/highlights/MidAtldrought/vin1999.jpg Foreign Agriculture Production Service. *Mid-Atlantic States 1999 Drought. Comparison of Vegetation Biomass 1999-1998.* Available: http://www.fas.usda.gov/pecad2/highlights/MidAtldrought/vindif_99_98.jpg 4. How did the 1999 drought affect vegetation in the Mid-Atlantic States? 5. Examine the weekly drought maps for 2002. 6. Using information from the maps, describe the state of the drought in Maryland for the year 2002. NWS. Climate Prediction Center. *2002 Drought Security Index by Division Palmer Archive.* Available: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer/2002/weekly_PALMER_2002.html Map showing weekly drought index. Service Learning Project Possible Action projects: 1. Conduct an erosion survey of the school or community. Look for areas of exposed soil. 2. Monitor environmental conditions such as: soil temperature and moisture, precipitation, air temperatures, wind speed 3. Develop an action plan 4. Repair damage caused by erosion by changing gradation, creating a storm drain, planting vegetation, etc.

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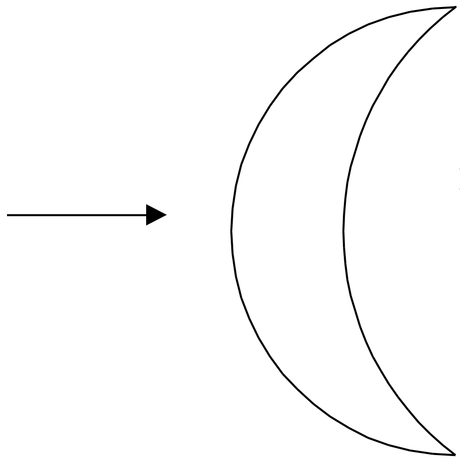
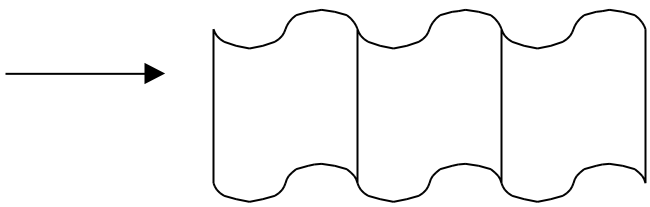
	Reflection: Develop a presentation illustrating the causes and effects of desertification, the possibility of it occurring in Maryland, and ways to prevent desertification. Suggested projects include: brochure, newspaper article, radio spot, poster, play, poem, etc. UNCCD. *United Nations Convention to Combat Desertification: An Explanatory Leaflet.* Available: http://www.unccd.int/convention/text/leaflet.php UNCCD. *Fact Sheet 2. The Causes of Desertification.* Available: http://www.unccd.int/publicinfo/factsheets/showFS.php?number=2 UNCCD. *Fact Sheet 3. The Consequences of Desertification.* Available: http://www.unccd.int/publicinfo/factsheets/showFS.php?number=2 INTEREST CENTER Dune erosion and restoration EcoISP. *Replanting Sea Oats Saves Dunes, Beaches.* Available: http://www.ecoisp.com/resources17.asp Compare sand dunes on Earth to those found on Mars. USGS. *Types of Dunes.* Available: http://pubs.usgs.gov/gip/deserts/dunes/
EVALUATE	***Journal Write:*** Write a paragraph describing the causes and effects of desertification. Cite data from your reading and laboratory investigation in your answer.

Materials per lab group:

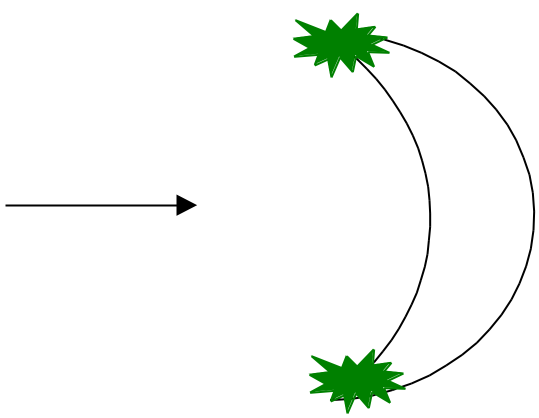
- Mixture of 65% sand, 25% pebbles and 10% small rocks
- Hair dryer
- Dissecting tray
- Three 400 mL beakers
- Ruler
- Broom
- Steel wool
- Grass
- Water
- Gloves



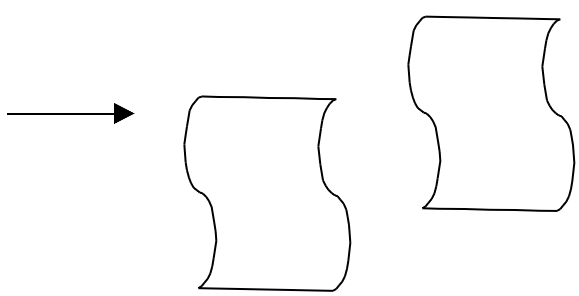
Barchan dune: Most common dune formation. Constant wind direction.



Transverse dunes: Strong winds and lots



Parabolic dune: Moderate winds, vegetation holds



Longitudinal dunes: High, variable winds and low amounts of

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The Effect of Wind Erosion

Part One:

1. Cover the bottom of the tray with 1 cm of the sand mixture.

Journal Write:

2. Draw a picture of the tray.

3. Turn the hair dryer on the lowest and coolest setting.

4. Blow air on the sand mixture at the front of the tray for several minutes.

Journal Write:

5. Diagram or describe how the landscape is changing.

6. How has the depth of the soil changed?

7. Is erosion occurring? List evidence to support your answer.

8. Does the wind affect all particles equally? List evidence to support your answer.

Part Two:

9. Remix the sand mixture and smooth out.

10. Simulate rain by pouring water over the sand.

Journal Write:

11. Draw a picture of the tray.

12. Turn the hair dryer on the lowest and coolest setting.

13. Blow air on the sand mixture at the front of the tray for several minutes.

Journal Write:

14. Diagram or describe how the landscape is changing.

15. How has the depth of the soil changed?

16. Is erosion occurring? List evidence to support your answer.

Part Three:

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17. Remix the moist sand mixture and smooth out.
18. Add vegetation or simulate vegetation (tease apart the steel wool partially bury in the sand). Wear gloves when handling steel wool.

Journal Write:

19. Draw a picture of the tray.
20. Turn the hair dryer on the lowest and coolest setting.
21. Blow air on the sand mixture at the front of the tray for several minutes.

Journal Write:

22. Diagram or describe how the landscape is changing.
23. How has the depth of the soil changed?
24. Is erosion occurring? List evidence to support your answer.

G/T Connection:

Part One

1. Cover the bottom of the tray with 1 cm of the sand mixture.

Journal Write:

2. Draw a picture of the tray.
3. Turn the hair dryer on the lowest and coolest setting.
4. Blow air on the sand mixture at the front of the tray for a few seconds.
5. Observe the movement of particles. Hint: there are three types of movement

Journal Write:

6. Which particles are moving?
7. Diagram or describe their movement.

8. What is the relationship between particle size, weight and movement?

   Continue blowing for several minutes.

Journal Write:

9. How can you tell where the air is touching the sand? Diagram or describe how the landscape is changing

10. Form a large sand dune across the center of the tray.

11. Continue blowing for several minutes.

Journal Write:

12. Diagram the shape of the sand dunes. Indicate the direction of the wind.

13. Continue blowing for several minutes.

14. Diagram the shape of the sand dunes. Indicate the direction of the wind.

15. How has the shape of the dune changed?

16. Increase the strength of the wind. Continue blowing for several minutes.

17. Diagram the shape of the sand dunes. Indicate the direction of the wind.

18. How has the shape of the dune changed?

Continue on with parts two and three.

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Lesson 10: SEDIMENTARY ROCK

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.2 The student will pose meaningful, answerable scientific questions.

1.2.3 The student will formulate a working hypothesis.

1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.

Indicator(s): Core Learning Goal 2

2.4.1 The student will compare the origin and structure of igneous, metamorphic and sedimentary rocks. Assessment limits (at least) - Origin, texture (crystal size, shape) and mineral composition of common rock groups

2.4.2 The student will explain how the transfer of energy drives the rock cycle. Assessment limits (at least) - Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition)

Student Outcome(s):

1. The student will be able to compare the two general categories of sedimentary rocks by examining their origin, texture and composition.
2. The student will be able to illustrate how sedimentary rocks are formed through lithification by observing cementation and compaction.

Brief Description:

In this lesson, students synthesize the action of weathering, erosion and deposition in the formation of unconsolidated sedimentary rocks. They explore how sedimentary rock layers are developed and observe how lithification occurs. Students examine sedimentary rocks and develop the characteristics of clastic/detrital and chemical sedimentary rocks.

Background knowledge / teacher notes:

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Weathering, erosion, deposition form unconsolidated sedimentary rock layers called strata or bedding. If these sediments are buried and compacted, lithification begins. The weight of overlying sediments squeezes out excess water and the layers compact. Sediments that are buried deep under many layers experience an increase in temperature and pressure that may cause chemical and mineral changes. Particles are cemented together as minerals either overgrow sediments uniting them or as minerals precipitate out of groundwater between sediments.

Sedimentary rocks are divided into two broad categories: clastic or detrital sedimentary rocks and chemical or nonclastic sedimentary rocks. Clastic (broken) rocks are the result of loose sediments broken off by weathering and transported great distances by rivers and streams. Conglomerates are coarse-grained rocks with rounded edges from abrasion during transport. Breccias are also coarse-grained, but lack rounded edges indicating a shorter period of transport. Medium-grained clastic rocks such as sandstone are highly porous often providing spaces for oil, natural gas or groundwater. Fine-grained clastic sedimentary rocks are composed of varying combinations of silt, mud and clay. Rocks such as siltstone, mudstone and shale have low porosity, serving as a barrier to oil and groundwater.

Chemical sedimentary rocks, such as calcite, halite, and gypsum are called evaporates. As water evaporates or the concentration of minerals increases, minerals precipitate out of solution and settle on the bottom. If the water continues to evaporate, these layers may be exposed forming salt flats like the Bonneville Salt Flats in Utah, where Morton Salt Company harvests salt. Other sedimentary rocks form from lithification of organic material such as skeletons of diatoms or coral reefs.

Excellent pictures of sedimentary rocks and their characteristics may be found at
Georgia Perimeter College. *Sedimentary Rocks.*
Available: http://www.dc.peachnet.edu/~pgore/geology/geo101/sedrx.htm

Lesson Description:

ENGAGE	Give each student a sedimentary rock with layers or a picture of a sedimentary rock.

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	Charter College of Education, California State University. World Builders. *Sedimentary Rocks.* Image Available: http://curriculum.calstatela.edu/courses/builders/lessons/less/les2/sedim.html NECSI. *Fossil layers.* Sedimentary rock image. Available: http://necsi.org/projects/evolution/evidence/layers/evidence_layers.html Think-Pair –Share 1. Are these igneous rocks? *No* 2. If these are not igneous rocks, how were they formed? *Weathering and erosion and then somehow put together.* 3. What type of rocks are these? *Sedimentary* 4. Brainstorm questions about these rocks. 5. List the questions on the board or overhead.
EXPLORE	1. Within your small groups, discuss the questions generated by the class along with the following questions: · Why do they have layers, strata or bedding? · Where did these rocks come from? *Weathering and erosion* · Hypothesize how these rocks were formed. · How do they turn into rock? 2. Work with a partner and illustrate how these rocks might have been formed. Materials: three different colors of clay, wax paper Discussion: Compare models and discuss hypotheses. Adaptive Strategy: Demonstrate the formation of layers 1. Add sand, gravel, and soil to a jar. 2. Fill the jar with water.

	3. Add a lid and shake. 4. Let settle and observe. Lithification: Making sedimentary rocks through cementation Materials per lab group: glucose solution, plastic disposable glass or petri dish, sand, small pieces of gravel Teacher Note: glue or salt water could be substituted for glucose solution. Directions: 1. Add enough sand to form a 1 cm thick layer on the bottom of the glass. Adaptive Strategy: Make rock layers by adding two to three layers of colored sand. 2. Add just enough glucose solution to cover the sand. 3. Let sit. If possible, place in front of a fan to speed up evaporation. Read to be informed about lithification Glencoe-McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. pp. 124-127. Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 41-42 and p. 46. Or other similar text passages. ***Journal Write:*** Create a graphic organizer comparing the different types of lithification. *Cementation and compaction.*
EXPLAIN	1. When the glucose solution has dried, gently separate the sand and glucose solution from the glass. 2. Examine the mixture. ***Journal Write:*** 3. Has lithification occurred? Cite evidence from the investigation to support your answer.

	4. What type of lithification does this illustrate? *cementation* 5. Which type of lithification did the modeling clay demonstrate? *Compaction*
EXTEND	Materials per lab group: one or two igneous rocks, several sedimentary rocks if possible: conglomerate, breccia, sandstone, shale or rock with fossil, hand lens, colored pencils (optional) Teacher Note: If you do not have enough sedimentary rocks, set up stations and have the students rotate through a set of stations or use pictures. NECSI. *Fossil layers.* Sedimentary rock with fossil image. Available: http://necsi.org/projects/evolution/evidence/layers/evidence_layers.html Excellent pictures of sedimentary rocks and their characteristics may be found at Georgia Perimeter College. *Sedimentary Rocks.* Available: http://www.dc.peachnet.edu/~pgore/geology/geo101/sedrx.htm Directions: 1. Make a data table to record observations. 2. Examine each of the sedimentary rocks. 3. Draw a picture of each rock. 4. List the major characteristics of each rock. Adaptive Strategy: Provide the students with guide questions to use as they examine the rocks. Read to be informed about types of sedimentary rocks. Glencoe-McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. pp. 124-132. Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth

	Science. pp. 42-45. Or other similar text passages. Adaptive Strategy: This site has a clear explanation and good diagrams illustrating the formation of sedimentary rocks. Charter College of Education, California State University. World Builders. *How are sedimentary rocks formed?* Available: http://curriculum.calstatela.edu/courses/builders/lessons/less/les2/formsed.html Charter College of Education, California State University. World Builders. *Sedimentary Rocks.* Available: http://curriculum.calstatela.edu/courses/builders/lessons/less/les2/sedim.html ***Journal Write:*** 1. Create a graphic organizer to compare clastic/detrital to chemical sedimentary rocks. Important identifying characteristics: composition, grain size, shape of particles, porosity, method or location of formation. 2. Using these characteristics, try and identify the rocks from the lab. Discussion: 1. Show a picture of the salt flats or White cliffs of Dover. Utah History to Go. *Bonneville Salt Flats.* Available: http://historytogo.utah.gov/saltflats.html Dover Museum. *Discover the White Cliffs.* Available: http://www.dover.gov.uk/museum/resource/articles/cliffs.htm 2. How were these rocks formed?

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	3. How do they differ from other sedimentary rocks? <u>G/T Connection:</u> 1. Read to be informed about diatomaceous earth, its formation and economic uses. Hydromall. *What is Diatomaceous earth?* Available: http://www.hydromall.com/happy_grower16.html Or other similar websites. 2. Examine microscope slides of diatoms. INTEREST CENTER Utah.com *Bonneville Salt Flats.* Available: http://www.utah.com/playgrounds/bonneville_salt.htm Utah History to Go. *Bonneville Salt Flats.* Available: http://historytogo.utah.gov/saltflats.html Dover Museum. *Discover the White Cliffs.* Available: http://www.dover.gov.uk/museum/resource/articles/cliffs.htm Gives the geology of the cliffs along with a picture. Calvert County Living. *Fossils of Calvert Cliff.* Available: http://calvert-county.com/fossils.htm Itano. *Maryland Paleocene Fossils*. Available: http://www.itano.net/fossils/marylan2/marylan2.htm
EVALUATE	***Journal Write:*** Write a paragraph describing the formation of sedimentary rocks through lithification (cementation and compaction). Include the two

	general categories of sedimentary rocks. Be sure to include evidence from your laboratory investigation, and refer to your graphic organizer.

Materials per lab group:

- One or two igneous rocks
- Sedimentary rocks: conglomerate, breccia, sandstone, shale, rock with fossil
- Hand lens
- Colored pencils (optional)
- Glucose solution
- Plastic disposable glass or petri dish
- Sand: different colors
- Gravel
- Glue
- Salt water
- Clear jar with lid
- Soil
- Water
- Microscope slides of diatoms
- Microscope

Earth/Space Systems Science
Unit IV: The Geosphere

Lesson 11: RELATIVE DATING

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

1.5.7 The student will use, explain, and/or construct various classification systems.

1.7.5 The student will investigate career possibilities in the various areas of science.

Indicator(s): Core Learning Goal 2

2.5.1 The student will apply geologic principles used to date Earth's geologic and biologic events. Assessment limits (at least) – Relative dating (superposition in rock columns, core samples, unconformities; uniformitarianism; cross-cutting relationships; correlation of rock layers, fossils)

Student Outcome(s):

The student will be able to determine the relative age of geologic formations by employing the principle of uniformitarianism, the law of superposition, and index fossils.

Brief Description:

Students investigate how relative dating can be used to determine the age of geologic formations. Index fossils and correlation of rock layers is introduced. Students use these concepts to examine the geologic time scale, its major events and identify eras, periods and epochs.

Background knowledge / teacher notes:

From the results of studies on the origins of the various kinds of rocks (petrology), coupled with studies of rock layering (stratigraphy) and the evolution of life (paleontology), geologists reconstruct the sequence of events that has shaped the Earth's surface. Their studies show, for example, that during a particular episode the land surface was raised in one part of the world to form high plateaus and mountain ranges. After the uplift of the land, the forces of erosion attacked the highlands and the eroded rock debris was transported and redeposited in the lowlands. During the same interval of time in another part of the world, the land surface subsided and was covered by the seas. With the sinking of the land surface, sediments were deposited on the ocean floor. The evidence of the pre-existence of ancient mountain ranges lies in the nature of the eroded rock debris, and the evidence of the seas' former presence is, in part, the fossil forms of marine life that accumulated with the bottom sediments.

Such recurring events as mountain building and sea encroachment, of which the rocks themselves are records, comprise units of geologic time even though the actual dates of the events are unknown. By comparison, the history of mankind is similarly organized into relative units of time. We speak of human events as occurring either BC or AD, broad divisions of time. Shorter spans are measured by the dynasties of ancient Egypt or by the reigns of kings and queens in Europe. Geologists have done the same thing to geologic time by dividing the Earth's history into Eras, broad spans based on the general character of life that existed during these times, and Periods, shorter spans based partly on evidence of major disturbances of the Earth's crust.

Reprinted from: USGS. *Time and Change/ Using Radioactive Decay to Determine Geologic Age*.
Available: http://pubs.usgs.gov/gip/geotime/

For a good discussion on relative time vs. absolute time see
Geology and Geophysics. University of Calgary. *Geological Time Scale*.
Available: http://www.geo.ucalgary.ca/~macrae/timescale/timescale.html

Lesson Description:

ENGAGE	Place the following list on the overhead, chalkboard, or on a piece of chart paper: · the first manned space flight · the first successful satellite launch

	· the first human on the moon · the discovery of America · the Wright Brothers' first successful airplane · the invention of the "horseless carriage" Working in pair, students arrange these events in chronological order, and explain to the class how they arrived at their decisions. Teacher Note: It is not necessary to provide dates for any of these events, or to tell how much time elapsed between events. *Correct sequence* · *the discovery of America* · *the invention of the "horseless carriage"* · *the Wright Brothers' first successful airplane* · *the first successful satellite launch* · *the first manned space flight* · *the first human on the moon* Think-Pair-Share/Discussion: 1. How are we able to determine the order of events without know dates? *This is called relative dating vs. absolute dating.* 2. View a picture of the Grand Canyon from space. Earth From Space. *Grand Canyon.* Available: http://earth.jsc.nasa.gov/feat.html Under "Available Views", scroll down to Grand Canyon. Choose image STS61A-48-0091 "Grand Canyon." 3. View a picture showing the canyon layers Department of Earth and Atmospheric Sciences. Cornell University. *Photo Gallery. Undeformed strata of the Grand Canyon* Available: http://www.geo.cornell.edu/geology/classes/geol326/photos.html 4. How was the Grand Canyon formed? *River erosion.*

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	5. What type of rock are we examining? *Sedimentary* 6. How can you tell? *Strata are visible* 7. Where do you think oldest rocks are located? *Bottom layer of the canyon.* 8. Where are the youngest rocks? *Top layer* 9. Show a picture of folded strata. Department of Earth and Atmospheric Sciences. Cornell University. *Photo Gallery. Folded Strata in Alps.* Available: http://www.geo.cornell.edu/geology/classes/geol326/photos.html 10. Where do you think oldest rocks are located? *Bottom layer* 11. Where are the youngest rocks? *Top layer* 12. You are using the law of Superposition to decide where the oldest and youngest rocks are located. What is the law of superposition? *In an undisturbed horizontal sequence of rocks, the oldest rock layers will be on the bottom, with successively younger rocks on top of these* Adaptive Strategy: 1. Show students a stack of newspapers on a desk or table in front of the room. 2. Explain that this represents two weeks of the daily paper. 3. You need to find a paper from exactly a week ago. 4. What is the quickest way to find this newspaper? 5. *Look in the middle of the stack.* 6. Why do we assume that this is where we'll find this paper? *Older papers are on the bottom; newer ones should be close to the top of the stack.*
EXPLORE	Read to be informed about uniformitarianism, law of superposition,

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	original horizontally and index fossils. Teacher Note: Avoid exceptions such as cross-cutting and unconformities at this time. Glencoe McGraw-Hill. (2002). Glencoe Earth Science Geology the Environment, the Universe. pp. 557-558 and 568 Prentice-Hall. (2002). Lutgens & Tarbuck. Foundations of Earth Science. pp. 206 and 210-214. Or other similar text passages.
EXPLAIN	***Journal Write:*** 1. What is relative dating? 2. How are fossils used to determine the relative age of rock layers? Discussion: 1. What is the principle of uniformitarianism? *The principle of uniformity states that the same geologic processes (erosion, deposition, weathering, rock cycle…) that occur today and have also occurred in the past. Only the rate, intensity and scale have changed. This principle is fundamental to geologic thinking and underlies the whole development of the science of geology.* 2. Why is it important in relative dating? 3. How can we use fossils to help order or date rock layers? *Fossils found in the deepest layer of rocks in an area represent the oldest forms of life in that rock formation. By correlating fossils from various parts of the world, scientists are able to give relative ages to particular strata. Relative dating tells scientists if a rock layer is "older" or "younger" than another.*
EXTEND	Who's On First? Relative Dating Activity Materials per lab group**:** sequence cards with nonsense syllables in random order, envelope labeled Set A Teacher Note: The cards should be duplicated, laminated, and cut

	into sets and randomly mixed before given to students. For Set B, you may want to color code each organism type (i.e., color the trilobites blue) before you laminate and cut the cards apart. Store cards in labeled envelopes. Directions: 1. Spread the cards from Set A (nonsense syllables) on the table. 2. Determine the correct sequence of the eight cards by comparing letters that are common to individual cards and, therefore, overlap. <u>Adaptive Strategy</u>: Model how to begin sequencing the cards by doing steps 3 – 7 with the class or groups that need help. 3. The first card in the sequence has "Card 1, Set A" in the lower left-hand corner and represents the bottom of the sequence. 4. If letters "T" and "C" represent fossils in the oldest rock layer, they are the oldest fossils 5. Look for a card that has either a "T" or "C" written on it. 6. Since this card has a common letter with the first card, it must go on top of the "TC" card. The fossils represented by the letters on this card are "younger" than the "T" or "C" fossils on the "TC" card, which represents fossils in the oldest rock layer. 7. Sequence the remaining cards by using the same process. 8. When you finish, you will have a stack of cards representing the rock sequence. The top card represents the youngest fossils and the "TC" card represent the oldest fossil. ***Journal Write:*** 9. Record the sequence of letters (using each letter only once) starting with the top card. Remember, the letters will be in order from youngest to oldest. Teacher Note: None of the letters in this sequence may be reversed

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	and still be correct. The sequence must be exactly in the order as written. It is not uncommon to have students reverse the M and D and begin the sequence with DM because that is the way they are printed on the card. It is good at this time to remind them that these letters represent fossils in a rock layer and that one fossil next to another within a rock layer implies no particular sequencing; they both are approximately the same age as the rock layer. 10. Is X older than M? *X" is older than "M" because it appears in an older rock strata (i.e., the card beneath the "DM" card). "M" is not present in the card below it in the stack and is, therefore, younger.* 11. Is rock layer D the same age as M? *Since fossils D and M died and were deposited in the same rock layer, they both are the same age as the rock layer.* 12. Why is D in the rock layer OXD older than the rock layer D of DM? *Using the Law of Superposition, the rock layer OXD is beneath rock layer DM and, therefore, is older. The fossils within rock layer OXD (i.e., fossils O, X, and D) are older than the fossils in the layer above it (i.e., D and M in rock layer DM). Therefore, D in the rock layer OXD is older than D in the rock layer DM.* From The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record. *Who's on First? A Relative Dating Activity.* Available: http://www.ucmp.berkeley.edu/fosrec/BarBar.html Discuss the purpose of index fossils. *Rare or distinct* fossils are *used to match rock layers or date rock layers. This is called Correlation.*

	Materials per lab group**:** sequence cards with nonsense: sketches of fossils in random order, envelope labeled Set B Directions Part Two: 1. Spread the cards from Set B (sketches of fossils) on the table. 2. Carefully examine the second set of cards containing sketches of fossils on them. 3. Each card represents a particular rock layer and fossils that found in that rock stratum. 4. All of the fossils represented are found in sedimentary rocks of formed in the sea. Figure One gives background information on the individual fossils. 5. The oldest rock layer is marked with the letter "M" in the lower left-hand corner. 6. Ignore the other letters on the cards at this time. 7. Find a rock layer that has at least one of the fossils you found in the oldest rock layer. 8. This rock layer is younger as indicated by the appearance of new fossils in the rock stratum. 9. Keep in mind that extinction is forever. Once an organism disappears from the sequence it cannot reappear later. 10. Use this information to sequence the cards in a vertical stack of fossils in rock strata. 11. Arrange them from oldest to youngest with the oldest layer on the bottom and the youngest on top. ***Journal Write:*** 12. Using the letters printed in the lower left-hand corner of each card, write the sequence of letters from the youngest layer to the oldest layer (i.e., from the top of the vertical stack to the bottom). 13. Which fossil organisms could possibly be used as index fossils? *The graptolite, placoderm, ammonite, ichthyosaur, and shark's*

tooth could be used as index fossils since they are found in only one layer. Technically, however, given only this set of strata, one cannot say that the shark's tooth and ichthyosaur could be used as index fossils because we do not know if they continue in younger rock layers above this set of strata.

14. Name three organisms represented that probably could not be used as index fossils and explain why. *The brachiopod, crinoid, eurypterid, foraminifera, gastropod, horn coral, pelecypod, and trilobite could not be used as index fossils since they overlap more than one stratum*

Discussion:

1. How can we study rock strata at the bottom of the ocean? *We can take core samples*
2. Read a little of the following article to the class and show the pictures of a core sample.

NASA JSC. *Lunar Sample Facility Tour. Core and Saw Area.* Available: http://www-curator.jsc.nasa.gov/curator/lunar/tour/CoreBS.htm

Career Connection:

3. Why do we want to know about rock strata? Read a little of the following article to the class and show the pictures of the core samples.

the Lamp. *Where Exxon stores its past and future.* Available: http://www.exxonmobil.com/news/publications/c_winter00_lamp/c_rock_samples.html

Journal Write:

1. What is a core sample?

	2. What information may be learned from examining a core sample?
EVALUATE	***Journal Write***: Examine how the relative age of a geologic formation can be determined using the principle of uniformitarianism, the law of superposition and index fossils. Cite examples from your class activities to support your answer.

Materials per lab group:

- Sequence cards with nonsense letters
- Sequence cards with sketches of fossils
- Envelope labeled Set A
- Envelope labeled Set B

Place the following items in order

- the first manned space flight
- the first successful satellite launch
- the discovery of America
- the first human on the moon
- the Wright Brothers' first successful airplane flight
- the invention of the "horseless carriage"

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Who's On First? Relative Dating Activity

Materials per lab group: sequence cards with nonsense syllables in random order, envelope labeled Set A

Directions:

1. Spread the cards from Set A (nonsense syllables) on the table.
2. Determine the correct sequence of the eight cards by comparing letters that are common to individual cards and, therefore, overlap.
3. The first card in the sequence has "Card 1, Set A" in the lower left-hand corner and represents the bottom of the sequence.
4. If letters "T" and "C" represent fossils in the oldest rock layer, they are the oldest fossils.
5. Look for a card that has either a "T" or "C" written on it.
6. Since this card has a common letter with the first card, it must go on top of the "TC" card. The fossils represented by the letters on this card are "younger" than the "T" or "C" fossils on the "TC" card, which represents fossils in the oldest rock layer.
7. Sequence the remaining cards by using the same process.
8. When you finish, you will have a stack of cards representing the rock sequence. The top card represents the youngest fossils and the "TC" card represent the oldest fossil.

Journal Write:

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9. Record the sequence of letters (using each letter only once) starting with the top card. Remember, the letters will be in order from youngest to oldest.
10. Is X older than M?
11. Is rock layer D the same age as M?
12. Why is D in the rock layer OXD older than the rock layer D of DM?

Materials per lab group**:** sequence cards with nonsense: sketches of fossils in random order, envelope labeled Set B

Directions Part Two:

13. Spread the cards from Set B (sketches of fossils) on the table.
14. Carefully examine the second set of cards containing sketches of fossils on them.
15. Each card represents a particular rock layer and fossils that found in that rock stratum.
16. All of the fossils represented are found in sedimentary rocks of formed in the sea. Figure One gives background information on the individual fossils.
17. The oldest rock layer is marked with the letter "M" in the lower left-hand corner.
18. Ignore the other letters on the cards at this time.
19. Find a rock layer that has at least one of the fossils you found in the oldest rock layer.
20. This rock layer is younger as indicated by the appearance of new fossils in the rock stratum.

21. Keep in mind that extinction is forever. Once an organism disappears from the sequence it cannot reappear later.
22. Use this information to sequence the cards in a vertical stack of fossils in rock strata.
23. Arrange them from oldest to youngest with the oldest layer on the bottom and the youngest on top.

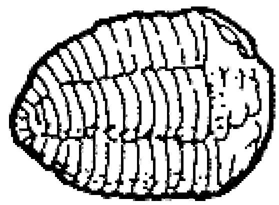
Journal Write:

24. Using the letters printed in the lower left-hand corner of each card, write the sequence of letters from the youngest layer to the oldest layer (i.e., from the top of the vertical stack to the bottom).
25. Which fossil organisms could possibly be used as index fossils?
26. Name three organisms represented that probably could not be used as index fossils and explain why.

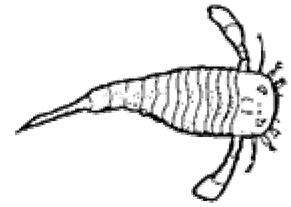
From The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record. *Who's on First? A Relative Dating Activity.* Available: http://www.ucmp.berkeley.edu/fosrec/BarBar.html

27. Figure One: Sketches of Marine Fossil Organisms (Not to Scale)

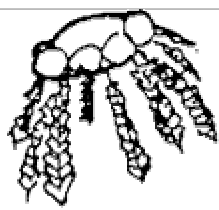
NAME: Brachiopod
PHYLUM: Brachiopoda
DESCRIPTION: "Lampshells"; exclusively marine organisms with soft bodies and bivalve shells; many living species



NAME: Trilobite
PHYLUM: Arthropoda
DESCRIPTION: Three-lobed body; burrowing, crawling, and swimming forms; extinct



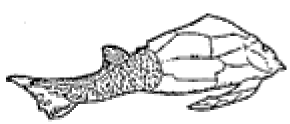
NAME: Eurypterid
PHYLUM: Arthropoda
DESCRIPTION: Many were large (a few rare species were 5 feet in length); crawling and swimming forms; extinct



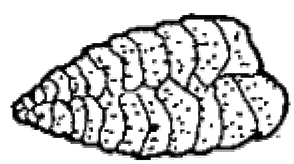
NAME: Graptolite
PHYLUM: Chordata
DESCRIPTION: Primitive form of chordate; floating form with branched stalks; extinct

NAME: Horn coral
PHYLUM: Coelenterata (Cnidaria)
DESCRIPTION: Jellyfish relative with stony (Cnidaria)(calcareous) exoskeleton found in reef environments; extinct

NAME: Crinoid
PHYLUM: Echinodermata
DESCRIPTION: Multibranched relative of starfish; lives attached to the ocean bottom; some living species ("sea lilies")



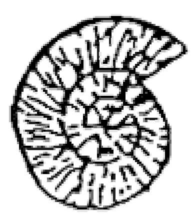
NAME: Placoderm
PHYLUM: Vertebrata
DESCRIPTION: Primitive armored fish; extinct



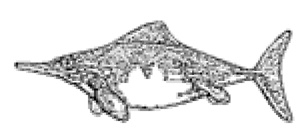
NAME: Foraminifera (microscopic type)
PHYLUM: Protozoa (Sarcodina)
DESCRIPTION: Shelled, amoeba-like organism

NAME: Gastropod
PHYLUM: Mollusca
DESCRIPTION: Snails and relatives; many living species

NAME: Pelecypod



NAME: Ammonite

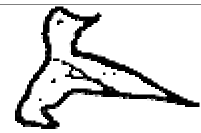


NAME: Icthyosaur

PHYLUM: Mollusca
DESCRIPTION: Clams and oysters; many living species

PHYLUM: Mollusca
DESCRIPTION: Squid-like animal with coiled, chambered shell; related to modern-day Nautilus

PHYLUM: Vertebrata
DESCRIPTION: Carnivore; air-breathing aquatic animal; extinct



NAME: Shark's tooth
PHYLUM: Vertebrata
DESCRIPTION: Cartilage fish; many living species

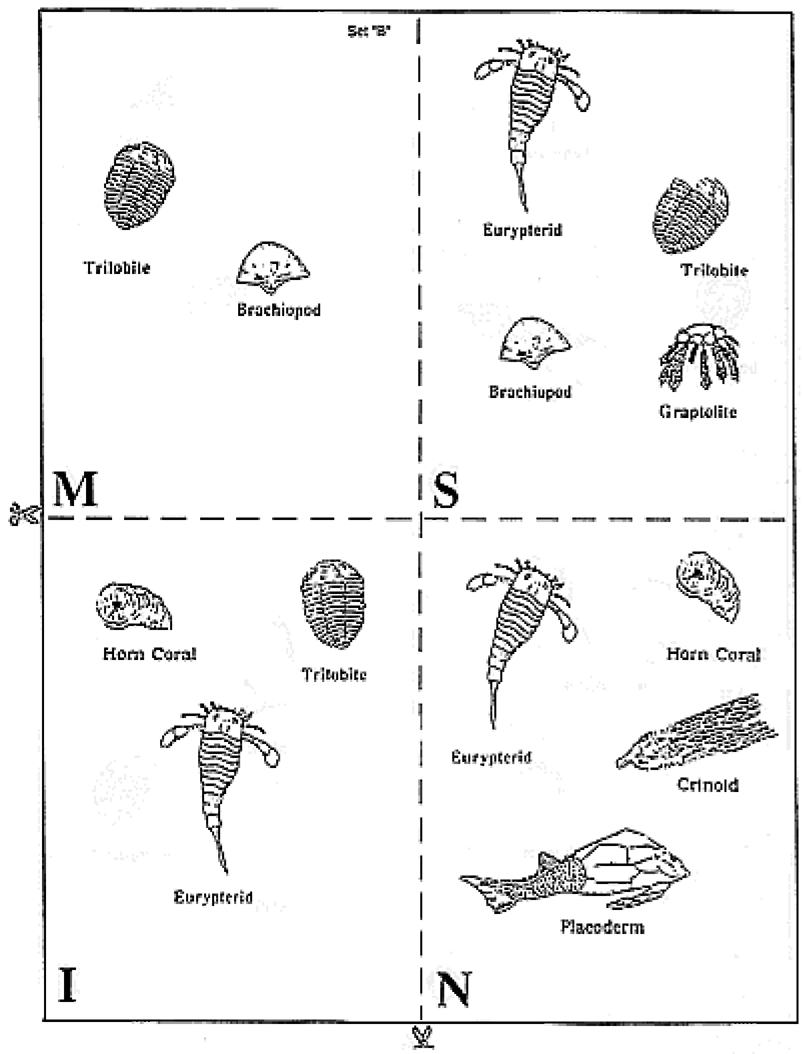
The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record. *Who's on First? A Relative Dating Activity.* Available: http://www.ucmp.berkeley.edu/fosrec/BarBar.html

Set A

TC Card I, Set "A"	CGA
AU	UBN
BN	NO
OXD	DM

The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record. *Who's on First? A Relative Dating Activity.* Available: http://www.ucmp.berkeley.edu/fosrec/BarBar.html

Set B



The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record. *Who's on First? A Relative Dating Activity.* Available: http://www.ucmp.berkeley.edu/fosrec/BarBar.html

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Unit IV: The Geosphere

Lesson 12: CROSS-CUTTING RELATIONSHIPS AND CORRELATION

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

1.5.6 The student will read a technical selection and interpret it appropriately.

Indicator(s): Core Learning Goal 2

2.5.1 The student will apply geologic principles used to date Earth's geologic and biologic events. Assessment limits (at least) – Relative dating (superposition in rock columns, core samples, unconformities; uniformitarianism; cross-cutting relationships; correlation of rock layers, fossils)

Student Outcome(s):

1. The student will be able to explain how cross-cutting and unconformities can affect rock strata by reading a technical selection and analyzing rock strata.
2. The student will be able to determine the correlation of rock layers by analyzing the placement of index fossils.

Brief Description:

Students explore more complex rock strata and apply the law of cross-cutting. Different types of unconformities are also presented. Using this knowledge, students determine the correlation between rock strata.

Background knowledge / teacher notes:

Unconformity: Buried erosion surface separating two rock masses, older exposed to erosion for long interval of time before deposition of younger. If older rocks were deformed and not horizontal at the time of subsequent deposition, the surface of separation represents an angular unconformity. If older rocks remained essentially horizontal during erosion, the surface separating them from younger rocks is called a disconformity. An unconformity that develops between massive igneous or metamorphic rocks that have been exposed to erosion and then covered by sedimentary rocks is called nonconformity.

Lesson Description:

ENGAGE	Discussion: 1. View a picture showing the canyon layers Department of Earth and Atmospheric Sciences. Cornell University. *Photo Gallery. Undeformed strata of the Grand Canyon* Available: http://www.geo.cornell.edu/geology/classes/geol326/photos.html 2. How can scientists study the geologic history of the earth? *Examine the rock layers, the arrangement of fossils.* 3. But sometimes the rock layers look like this. Show a picture of unconformity. Department of Earth Sciences. University of Southern California *An Unconformity in the Monterey Formation.* Available: http://earth.usc.edu/~boysun/photos.html Yukon Geology Program. *Unconformity*. Available: http://www.geology.gov.yk.ca/graphics/unconformity.jpg 4. What do you think happened to form these rock layers? Read about unconformities. This website has a simple explanation and easy to understand diagrams. The geography portal. *Online Tutorial Physical Geography. What is an Unconformity?* Available: http://www.kesgrave.suffolk.sch.uk/Curric/geog/unconf.html

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	5. What happened to this rock formation? Show a few pictures of angular unconformity. Department of Earth and Atmospheric Sciences. Cornell University. *Photo Gallery. Angular unconformity.* Available: http://www.geo.cornell.edu/geology/classes/geol326/photos.html Department of Earth and Environmental Sciences. Rensselaer Polytechnic Institute. *Angular unconformity*. Available: http://ees2.geo.rpi.edu/field_methods/pictures/100600%20class/unconformity_lg.JPG Show diagram detailing the formation of angular unconformity. (See resources) Department of Earth and Environmental Sciences. Rensselaer Polytechnic Institute. *Unconformity diagram.* Available: http://ees2.geo.rpi.edu/field_methods/pictures/092900%20class/UNCONFORMITY%20DIAGRAM.PDF or Department of Earth and Atmospheric Sciences. Cornell University. Introduction to Geological Sciences Week 8 *Unconformity*. Available: http://www.geo.cornell.edu/geology/classes/Geo101/graphics/unconformity.gif
EXPLORE	Read to be informed about the principle of cross-cutting relationships, inclusions, and unconformities. ***Journal Write:*** Create a graphic organizer to record the information. Glencoe McGraw-Hill. (2002). Glencoe Earth Science Geology the Environment, the Universe. pp. 559-561.

	Prentice-Hall. (2002). Lutgens & Tarbuck. Foundations of Earth Science. pp. 208-210. Or other similar text passages. Adaptive Strategy: Preview difficult vocabulary terms. For a simple straight-forward explanation of the Laws of Superposition and Cross-Cutting Relations visit: USGS. *The Laws of Superposition and Cross-Cutting Relations.* Available: http://pubs.usgs.gov/gip/fossils/laws.html Do the minilab from Glencoe McGraw-Hill. (2002). Glencoe Earth Science Geology the Environment, the Universe. Minilab "How is relative age determined?" p. 558 Materials per lab group: colored pencils, scissors Directions: 1. Draw four horizontal rock layers. 2. Label A-D 3. Color each a different color 4. Make a vertical intrusion from layers A-C. 5. Draw a diagonal line across the diagram. 6. Cut the diagram along this line 7. Move the left side forward so that the layers no longer match. ***Journal Write:*** 8. Can you still determine the relative age of the layers? *Yes the law of superposition still holds* 9. What do you know about the age of the intrusion? *Younger than A-C, older than D* 10. What does the line you drew and then cut represent? *fault*
EXPLAIN	Materials per lab group: clays of four different colors, wax paper, plastic knife Directions:

	1. Create a geologic formation that illustrates each of the following: intrusion, fault, inclusion, unconformity ***Journal Write:*** 2. Draw a diagram of your rock formation and label the parts. 3. Explain how each part represents the formation. 4. Exchange your formation with another group and analyze 5. Check with the group to see if your analysis is correct.
EXTEND	Relate the following scenario: *A paleontologist from Texas went on vacation to Montana where he discovered dinosaur bones in a particular layer of rock. He wondered if the same layer existed in Texas so he could find bones closer to his home. If that particular rock layer appeared on the Earth's surface, continuously, all the way from Montana to Texas he would be able to walk along the layer to follow it. That would be easy, but, unfortunately, the easy way never seems to work. In many cases layers of younger rocks cover the bone layer, and in other cases the bone layer is worn away by erosion. Both covering and erosion would make it impossible to follow the layer from Montana to Texas. Clearly, another method must be found. One of the most reliable ways to locate fossils is with other fossils. Certain widely found fossils represent animals that only lived on Earth for a very short time. Such fossils are called index fossils. When found in two geographically separated layers, scientists can say, with confidence that the layers are the same. Index fossils can be used to track a layer from Montana to Texas, or from Montana to France. They allow us to not only determine what layers contain other fossils, but also where in that layer certain fossils may be found. The process of determining if layers in different places are the same is called correlation.* Materials per lab group: four copies of figure one and two Explain that the figures show two stacks of rock layers, one in Montana and

	one in France. Directions: 1. Examine Figure One. Discuss the following two questions with your partner. · Which layers in Montana correlate with strata in France? · Which layer in France contains the same dinosaur fossil as layer "d" in Montana? 2. Make a hypothesis and using a colored pencil, connect the borders of the rock layers in Montana with those in France Adaptive Strategy: Use the transparency to model a connection for the class. 3. On the back of Figure One write the letter of the layer in France you predict will contain the dinosaur bone found in layer "d" in Montana. 4. Each fossil is found in only one layer in Montana and only one layer in France. Using the information shown in Figure Two, draw the fossils in the layers shown on the chart. Only one fossil is drawn in each space. Adaptive Strategy: Model how to draw the fossils in the correct layers. Index fossil two should be drawn only in layers c and i. 5. Using a colored pencil different from that used previously, connect the layers using the new fossil evidence. ***Journal Write:*** 6. Compare these connections with those made before. Was your hypothesis correct? 7. Which connection is most accurate? Use evidence from the activity to support your answer. 8. What was information was most helpful? 9. Which layer in France contains the dinosaur fossil? J 10. Show students a transparency of the solution, Figure Three. From The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The

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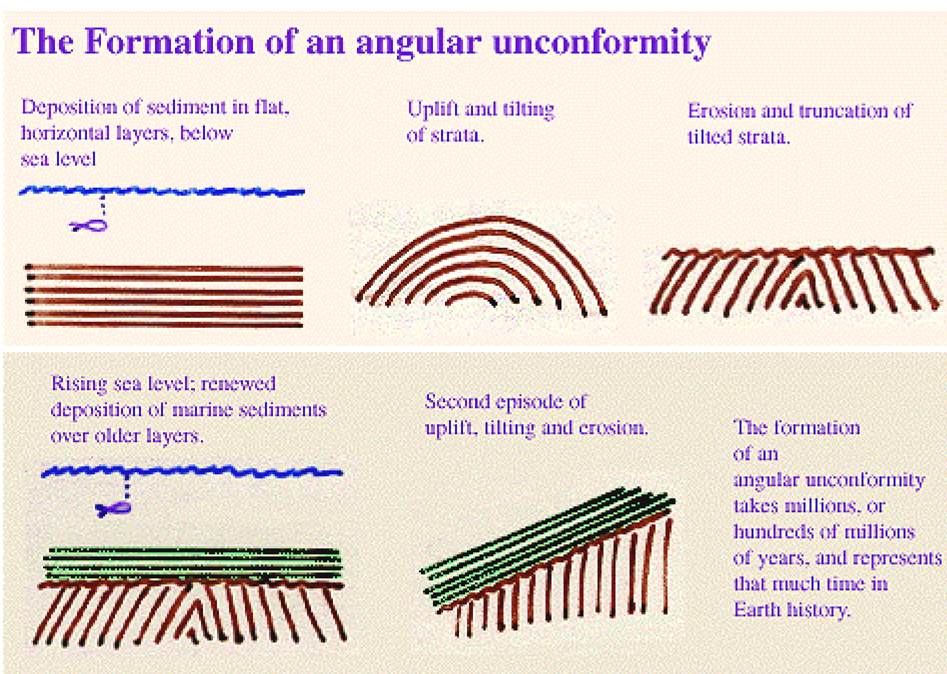
	Paleontological Society. Learning from the Fossil Record *Findasaurus*. Available: http://www.ucmp.berkeley.edu/fosrec/MunGun3.html INTEREST CENTER USGS. *Putting Events in Order.* Available: http://pubs.usgs.gov/gip/fossils/order.html
EVALUATE	***Journal Write:*** 1. Describe cross-cutting and unconformities and explain how they affect rock strata. 2. What are index fossils and how are they used to correlate layers? Cite examples from your class activities to support your answer.

Materials per lab group:

- Colored pencils
- Scissors
- Clays of four colors
- Wax paper
- Plastic knife



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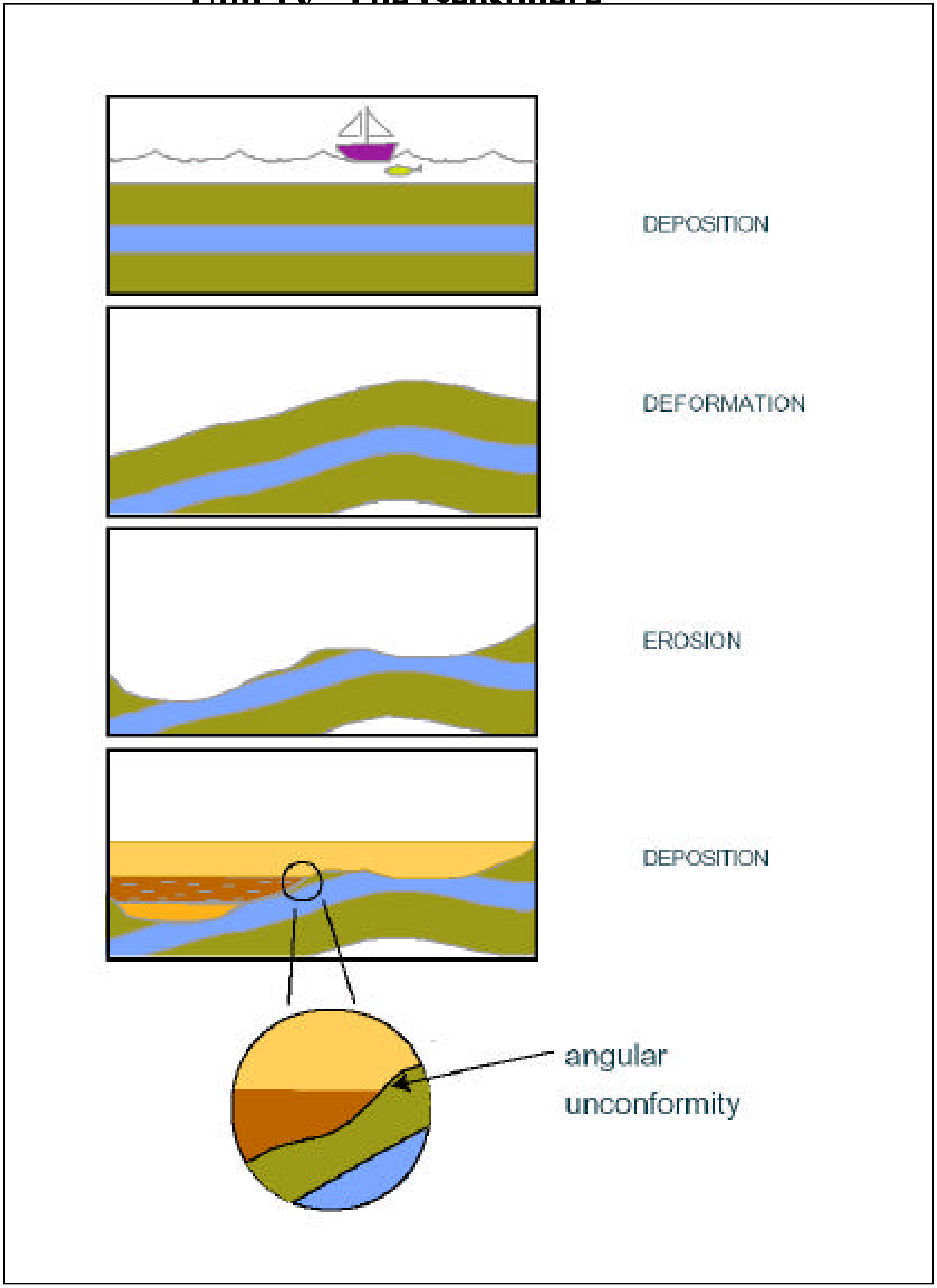
From Department of Earth and Atmospheric Sciences. Cornell University. Introduction to Geological Sciences Week 8 *Unconformity*.

Available: http://www.geo.cornell.edu/geology/classes/Geo101/graphics/unconformity.gif



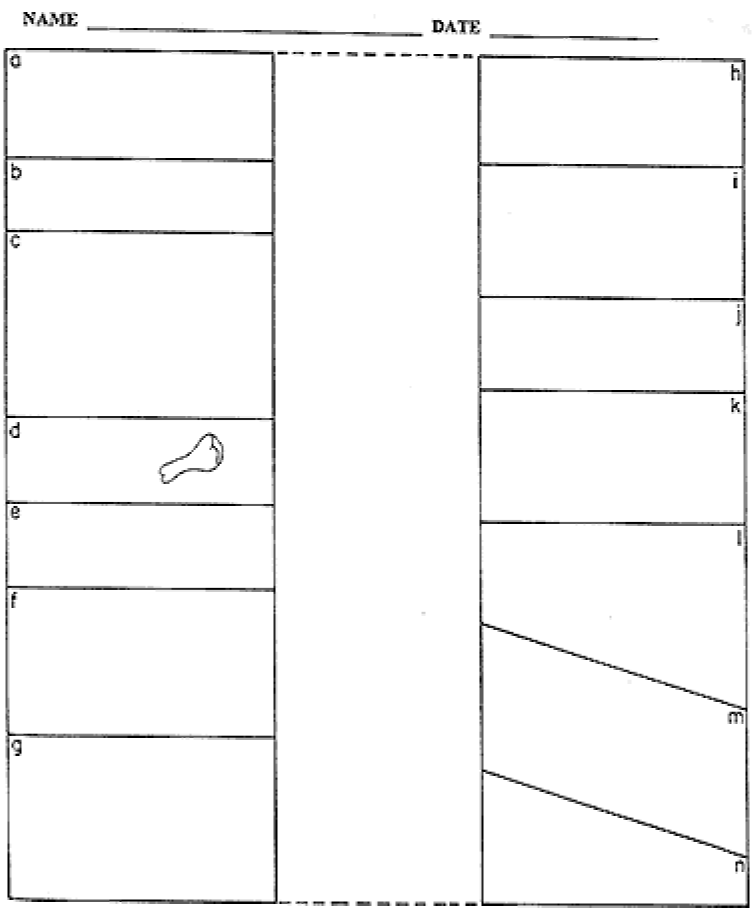
Department of Earth and Environmental Sciences. Rensselaer Polytechnic Institute.

Unconformity diagram.

Available:

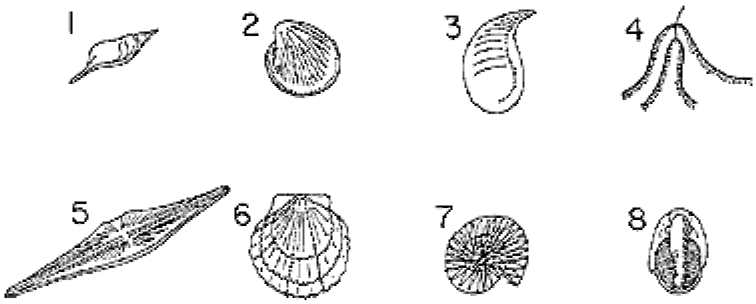
http://ees2.geo.rpi.edu/field_methods/pictures/092900%20class/UNCONFORMITY%20DIAGRAM.PDF

Figure 1. Chart showing rock layers identified by letter.



From The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record *Findasaurus*.
Available: http://www.ucmp.berkeley.edu/fosrec/MunGun3.html

Figure 2. Chart indicating index fossils and the rock layer in which each can be found.



Index Fossil Number	Found In Layer Letter(s)
1	b,h
2	c,i
3	l
4	f,m
5	e,k
6	a
7	d,j
8	g,n

From The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record *Findasaurus*.
Available: http://www.ucmp.berkeley.edu/fosrec/MunGun3.html

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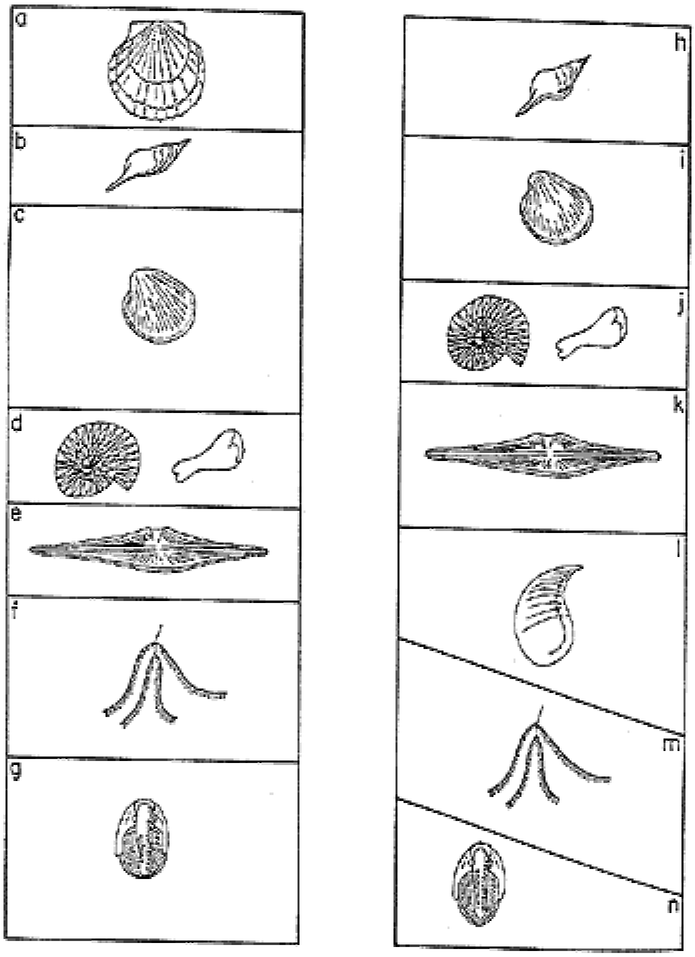
Figure 3. Answer key showing index fossils placed in the correct strata.



From The Museum of Paleontology of The University of California, Berkeley; the Regents of the University of California; and The Paleontological Society. Learning from the Fossil Record *Findasaurus*.

Available: http://www.ucmp.berkeley.edu/fosrec/MunGun3.html

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Lesson 13: RADIOACTIVE DECAY AND THE GEOLOGIC TIME SCALE

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.4.6 The student will describe trends revealed by data.

1.5.3 The student will use computers and/or graphing calculators to produce the visual materials (tables, graphs, and spreadsheets) that will be used for communicating results.

1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.

1.5.7 The student will use, explain, and/or construct various classification systems.

Indicator(s): Core Learning Goal 2

2.5.1 The student will apply geologic principles used to date Earth's geologic and biologic events. Assessment limits (at least) – Relative dating (superposition in rock columns, core samples, unconformities; uniformitarianism; cross-cutting relationships; correlation of rock layers, fossils). Absolute dating (radioactive dating)

2.5.2 The student will compare events in Earth's history that have been grouped according to similarities. Assessment limits (at least) – Geologic time (scale and magnitude) Era, period, epoch

Student Outcome(s):

1. The student will be able to explain how geologists use radioactive dating to determine the age of an Earth material by completing a simulation activity and reading a technical selection.
2. The student will be able to compare the major events on the geologic time scale by reading a technical selection, completing a graphic organizer, and making a journal entry.

Brief Description:

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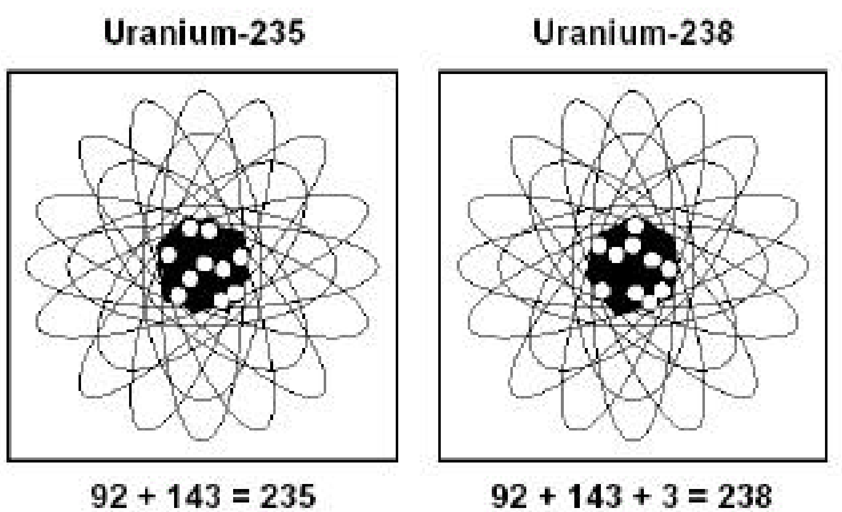
Students simulate the radioactive decay of an element and determine the element's half-life. Then using their knowledge of relative and absolute dating, student compare events on a geologic time scale.

Background knowledge / teacher notes:

"The nucleus in every atom of an element always has the same number of protons. However, the number of neutrons may vary. Atoms that contain the same number of protons, but different numbers of neutrons, are called isotopes of the element. All atoms are isotopes. To show which isotope of an element we are talking about, we total the number of protons and neutrons. Then we write the sum after the chemical symbol for the element. For example, in the nucleus of one isotope of uranium there are 92 protons and 143 neutrons. We refer to it as uranium-235 or U-235 (92 + 143 = 235). A second uranium isotope, which contains 3 additional neutrons, is uranium-238 or U-238 (92 + 143 + 3 = 238). (The number may also be written in superscript before the symbol: $_{235}$U or $_{238}$U.)

Isotopes of an element have different numbers of neutrons and the same number of protons. However, some proton-neutron combinations are more stable than others. Some unstable isotopes stabilize themselves by emitting or shooting out energy rays similar to X-rays. Others may emit particles from their nuclei and change into different elements. These rays and particles are called radiation, and the process of isotopes emitting them to become more stable is called radioactive decay."



From Science, Society and Nuclear Waste. *Atoms and Isotopes Review.*

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Available: http://www.rw.doe.gov/progdocs/edresource/unit_2_toc/22.pdf

Radioactive decay is a spontaneous process in which an isotope (the parent) loses particles from its nucleus to form an isotope of a new element (the daughter). The rate of decay is conveniently expressed in terms of an isotope's half-life, or the time it takes for one-half of a particular radioactive isotope in a sample to decay. Most radioactive isotopes have rapid rates of decay (that is, short half-lives) and lose their radioactivity within a few days or years. Some isotopes, however, decay slowly, and several of these are used as geologic clocks. The parent isotopes and corresponding daughter products most commonly used to determine the ages of ancient rocks are listed below:

Parent Isotope	Stable Daughter Product	Currently Accepted Half-life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	704 million years
Thorium-232	Lead-208	14.0 billion years
Rubidium-87	Strontium-87	48.8 billion years
Potassium-40	Argon-40	1.25 billion years
Samarium-147	Neodymium-143	106 billion years

The mathematical expression that relates radioactive decay to geologic time is called the age equation and is: t =1/delta ln(1 + D/P)

Where:

- t is the age of a rock or mineral specimen,
- D is the number of atoms of a daughter product today,
- P is the number of atoms of the parent product today,
- ln is the natural logarithm (logarithm to base e), and
- delta is the appropriate decay constant.

(The decay constant for each parent isotope is related to its half-life, t 1/2, by the following expression: t 1/2 = ln2/delta

Dating rocks by these radioactive timekeepers is simple in theory, but the laboratory procedures are complex. The numbers of parent and daughter isotopes in each specimen are determined by various kinds of analytical methods. The principal difficulty lies in measuring precisely very small amounts of isotopes.

Reprinted from: USGS Learning Web. *Geologic Age: Using Radioactive Decay to Determine Geologic Age*.

Available: http://interactive2.usgs.gov/learningweb/teachers/geoage.htm

The Talk of Origins Archive. *The Age of the Earth*

Available: http://www.talkorigins.org/origins/faqs-youngearth.html is an excellent site that discusses how the age of the Earth is determined. It provides detailed explanations for how scientists calculated the age of the Earth and gives a history of scientific thinking. **It is NOT appropriate for your students to visit.**

For detailed look at geologic time, relative time, major divisions of geologic time, index fossils, radiometric time scale, and the age of the earth,

USGS. *Geologic Time*.

Available: http://pubs.usgs.gov/gip/geotime/contents.html

For a good discussion on relative time vs. absolute time see

Geology and Geophysics. University of Calgary. *Geological Time Scale*.

Available: http://www.geo.ucalgary.ca/~macrae/timescale/timescale.html

Lesson Description:

ENGAGE	Share a story about a geologic find such as The Iceman. BBCi. *Death of the Iceman.* Available: http://www.bbc.co.uk/science/horizon/2001/iceman.shtml Discussion: 1. How do they know how old the mummy is? *Carbon 14* 2. What is Carbon 14? Teacher-led discussion about isotopes. 3. What is an isotope?

	4. How are isotopes identified? Adaptive Strategy: Read to be informed about isotopes and radioactive elements and radioactive dating. Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment, and the Universe. pp. 562-563 Or Prentice Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 14-15. Or other similar text passages.
EXPLORE	Explore what happens to unstable isotopes. Materials per lab group: 32 pennies, 32 other coins of the same type (all nickels), graphing calculator or graph paper. Radioactive Decay Directions: 1. Design a data table to record the results of the investigation. Adaptive Strategy: Discuss what information should be in the table: trials, number of pennies/Zactum, number of nickels in use/daughters of Zactum. If the names confuse your students, omit them. 2. The pennies you have been given represent the imaginary element "Zactum." 3. At the beginning of the experiment there are 32 Zactum coins and 0 DOZ (daughter of Zactum). Record this data in your table. 4. Drop the 32 pennies (parents) on to the table. 5. Count all the pennies that are head-side up and record this number in the data table. 6. Remove all the pennies that are head-side up; these have "decayed". 7. Add other coins (daughters of Zactum) to replace the decayed and removed Zactum until the total number of coins again equals 32. Adaptive Strategy: Model how to replace the lost Zactum with the other coin. 8. Record the number of pennies and other coins in the table.

	9. Repeat the process until there are no more Zactum and only daughters of Zactum are left. 10. Use the data collected in the table to construct a graph. Technology Connection: Use a graphing calculator to construct the graph. Adaptive Strategy: Remind students how to label the axis. 11. Draw a best-fit line for these points.
EXPLAIN	***Journal Write:*** 1. What does the graph illustrate about the relationship between the parent Zactum and the daughters of Zactum? 2. What happens during the radioactive decay of an element? *The isotopes disintegrate, a process called radioactive decay.* 3. What is an isotope? *Atoms that have the same number of protons, but different amounts of neutrons. Isotopes of an element have different mass numbers.* As a class, discuss the concepts demonstrated in the simulation. Introduce the idea of half-life. *The amount of time it takes for half of a parent isotope to turn into its daughter element is called the half-life. If you know the half-life of an isotope, and the amount of parent and daughter atoms present in a sample, you can calculate the age of the sample. Age determined by this method is called Absolute Dating.* ***Journal Write:*** 1. What is the half-life for Zactum? 2. Which is more accurate absolute or relative dating? Use evidence from the activities to support your answer? G/T Connection: Use the chart to relate radioactive isotopes and their half-lives to various events in history. (See resources) From Northwestern University Department of Geologic Sciences. *Simulating Radioactive Decay.*

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	Available: http://www.earth.northwestern.edu/people/seth/202/DECAY/decay.pennies.slow.html ***Journal Write:*** How far back can different isotopes be used to date events?
EXTEND	Using information from core samples, rock strata, and radioactive dating, we can construct a geologic time line. As a class, make a living geologic time line. Teacher Note: This will need to be done outside or in the hallway. Use the scale 100yards = 5 billion years. Place signs in the hallway or on the ground outside, marking off the eras, periods, and epochs Give each student a card containing the event on one side and the era, period and epoch on the other side. Directions: 1. Look your card. 2. What event do you represent? 3. In which era did this occur? 4. In which period did it occur? Teacher Note: explain how to interpret the time intervals on the card. 5. Using your era, period, and epoch as a guide, take your place on the geologic time line. 6. Share your event with the students on either side of you. ***Journal Write:*** 1. What are the differences among eras, periods, and epochs? 2. Make an analogy to illustrate the difference. *For example: hour–era, minute-period, second-epoch* Adaptive Strategy: Help students decode the geologic terms. This website

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	explains the meaning of the Latin names. USGS. *The Relative Time Scale*. Available: http://pubs.usgs.gov/gip/fossils/scale.html Read to be informed about events in Earth's geologic history. ***Journal Write:*** Create a graphic organizer to record the main events that occurred in each era, period, and epoch (if available). UCMP Geology. *Take Our Web Geologic Time Machine.* Available: http://www.ucmp.berkeley.edu/help/timeform.html Or other similar text passages that describe the main events of each era, period and epoch. Adaptive Strategy: Provide students with a graphic organizer. Choose one time period and model how to scan the paragraphs looking for the major events of the time period. Allow students to work in pairs. Preview difficult vocabulary terms. A website with less dense material is Enchanted Learning. *Geologic Time Scale.* Available: http://www.enchantedlearning.com/subjects/Geologictime.html INTEREST CENTER Enchanted Learning. *Paleocene Dinosaur Found* Available: http://www.enchantedlearning.com/subjects/dinosaurs/news/Paleocenedinos.shtml
EVALUATE	***Journal Write:*** 1. Explain how radioactive dating is used to determine the age of materials and support your explanation with evidence from your simulation and technical reading. 2. Using the information from your graphic organizer, compare the major

	events of the Cenozoic, Mesozoic and Paleozoic eras.

Materials per lab group:

- Geologic event cards
- Measuring tape
- 32 pennies
- 32 other coins: nickels
- Graphing calculator

Radioactive Decay

Materials per lab group: 32 pennies, 32 other coins of the same type (all nickels), graphing calculator or graph paper.

Directions:

1. Design a data table to record the results of the investigation.
2. The pennies you have been given represent the imaginary element “Zactum.”
3. At the beginning of the experiment there are 32 Zactum coins and 0 DOZ (daughter of Zactum). Record this data in your table.
4. Drop the 32 pennies (parents) on to the table.
5. Count all the pennies that are head-side up and record this number in the data table.
6. Remove all the pennies that are head-side up; these have "decayed".
7. Add other coins (daughters of Zactum) to replace the decayed and removed Zactum until the total number of coins again equals 32.
8. Record the number of pennies and other coins in the table.
9. Repeat the process until there are no more Zactum and only daughters of Zactum are left.
10. Use the data collected in the table to construct a graph.
11. Use a graphing calculator to construct the graph.
12. Draw a best-fit line for these points.

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Radioactive Decay

Isotope	Half Life	Maximum Age	Event
C14	5,570 years		
K40	1,400,000,000 years		
Rb87	47,000,000,000 years		
Sm147	106,000,000,000 years		

Time: (Years Before Present) Event:

500	Settlement of America by Europeans
2,487	Battle of Marathon
2,790	Founding of Rome
4,347	Sumerian Civilization
20,000	Settlement of America by Indians
1,500,000	First hominid appears
36,600,000	Start of the Oligocene
66,000,000	Formation of the Alps
66,400,000	Dinosaurs die out
570,000,000	First animals appear
4,500,000,000	Formation of the Earth
15,000,000,000	Formation of the Universe

Cenozoic Era **65 mya - present**	Misleadingly called the "age of mammals," this era equally represents the age of insects, flowering
Cenozoic Era Quaternary Period Holocene Epoch	This relatively warm period began at the end of the last ice age. It includes all of recorded
Cenozoic Era Quaternary Period Pleistocene Epoch	Many large land mammals (now extinct) lived during this time. Modern humans appear. The most recent
Cenozoic Era Tertiary Period Pliocene Epoch	This period of cooling and drying led to the spread of vast grasslands. Also, the land bridge between North

Cenozoic Era Tertiary Period Miocene Epoch	Grasslands and kelp forests first appeared. New global circulation patterns reduced the
Cenozoic Era Tertiary Period Oligocene Epoch	This relatively short epoch featured the first appearance of horses, and elephants with trunks.
Cenozoic Era Tertiary Period Eocene Epoch	Hoofed mammals, known as ungulates, became the prevalent mammals. Small species related to modern
Cenozoic Era Tertiary Period Paleocene Epoch	During the epoch, mammals drastically increased in number and diversity. They ranged from small

Mesozoic Era **245 – 65 mya**	Although dominated by the rise and fall of dinosaurs, this era also saw great developments in plants,
Mesozoic Era Cretaceous Period	Pangaea continued to spread. The first bird fossils are from this period, which ended with
Mesozoic Era Jurassic Period	Many diverse dinosaurs, birds, and marine animals lived during this period. Their remains formed
Mesozoic Era Triassic Period	Pangaea existed as Earth's single major landmass. Dinosaurs and conifers (cone-bearing trees) began

Paleozoic Era **544 – 245 mya**	This era began with an "explosion" of new animal species, but ended with the largest mass
Paleozoic Era Permian Period	Earth's crustal plates formed Pangaea. Flowering plants (gymnosperms) appear. The era ended
Paleozoic Era Carboniferous Period	During this period, new animals appeared that could lay their eggs on land. Plant remains from
Paleozoic Era Devonian Period	The first seed plants appeared, along with the first land insects. In the oceans, many new species

Paleozoic Era Silurian Period	Melting glaciers caused a rise in sea level, along with a more stable climate. Many jawed and jawless
Paleozoic Era Ordovician Period	Various invertebrates and primitive fish lived in the seas. The first land plants appeared. This period
Paleozoic Era Cambrian Period	An “explosion” of animal life occurred in a relatively short amount of time. Fossils from this period
Paleozoic Era Cambrian Period Tommotian Age	The first major radiation of animals happened during this brief time – only a few million years. Species

Precambrian Time	The oldest rocks and fossils are from this time. It represents the longest and oldest geologic time
Precambrian Time Proterozoic Era	Stable continents began to form. Life forms included bacteria and the first multicellular algae.
Precambrian Time Proterozoic Era Neoproterozoic Epoch	The earliest fossils of macroscopic, soft-bodied animals date back to this period.
Precambrian Time Archaean	Earth's atmosphere contained ammonia and methane. The first rocks and continental plates

Precambrian Time Hadean	This time represents the formation of our solar system, including the sun and Earth. Meteorites are

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Lesson 14: CONTINENTAL DRIFT

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.8 The student will defend the need for verifiable data.

1.4.3 The student will use experimental data from various investigators to validate results.

1.4.6 The student will describe trends revealed by data.

1.5.4 The student will create and/or interpret graphics (scale drawings, photographs, digital images, etc.).

1.5.6 The student will read a technical selection and interpret it appropriately.

Indicator(s): Core Learning Goal 2

2.1.2 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth.
Assessment limits (at least) – Tools (spectrometers, seismograph) Delivery systems (satellite-based, ground-based) Techniques (imaging, Geographic Information System, Global Positioning System, spectroscopy, Doppler, epicenter location/time-travel graphs)

2.4.3 The student will explain changes in Earth's surface using plate tectonics.
Assessment limits (at least) - Continental drift (rock/structure/climate/fossil evidence, jigsaw fit)

Student Outcome(s):

The student will be able to evaluate the theory of Continental Drift by analyzing geophysical evidence.

Brief Description:

Students generate a list of evidence supporting Wegener's theory of Continental Drift and discuss objections to the theory. By observing the behavior of iron filings in a magnetic field, students gain an understanding of the geomagnetic field that encircles the earth. Introduction of "polar wandering" presents an historic anomaly that can only be reconciled if the continents of North America and Eurasia are moved closer to their Pangaea positions.

Background knowledge / teacher notes:

A *fathometer* uses *sonar* or *sound waves* to measure the depth of the seafloor. *Altimeters*, such as those on the TOPEX/Poseidon satellite, use *radar* or *radio waves* to bounce signals off of the sea surface and record the time that it takes for each signal to return.

- Sound energy traveling through the water is used to measure the depth of the water. From this you can determine ocean floor topography.
- TOPEX/Poseidon uses radar to measure the height of the satellite above the sea. From this you can determine sea surface topography. The radar signal also measures wind speed and wave height.

Sailors have long used ropes with weights on the end to measure depths in shallow water. Often they tied knots 6 feet (1 *fathom*) apart in the rope for ease of measurement. The number of knots let out gave the depth in fathoms once the weight hit the bottom. Sir J. Clark Ross made the first accurate physical measurements of the deep ocean bottom in 1840. He measured a depth of 4435 meters off Antarctica. Later, scientists took extensive depth recordings on the *H.M.S. Challenger* using steam-driven winches with one-inch hemp rope that did not tangle. Scientists lowered the rope until it hit the bottom, recorded how much rope had been let out, and pulled the rope back. Letting out 3,000 meters of rope and reeling it back in could take as long as twelve hours.

Today, scientists can use sonar to make the same measurement. First, a sound or "ping" is sent toward the bottom. The "ping" reflects off the bottom, and an instrument (called a transducer) mounted in the ship's hull receives the reflected ping. A timer records the time from transmission to reception. The depth of the water is calculated by multiplying the time by the speed of sound through water. The distance traveled by the ping is twice the depth from the vessel to the bottom.

Data from all the instruments must be combined to generate the extremely accurate sea surface measurements needed to study currents and their effect on climate.

The TOPEX/Poseidon satellite's primary instrument for measuring ocean topography is a radar altimeter. The altimeter bounces a microwave pulse off the sea surface. By measuring how long the signal takes to return, the altimeter determines the distance between the satellite and the sea surface. Water vapor in the atmosphere slows down the return of the microwave signal. So an instrument called a radiometer is used to adjust for the influence of water in the atmosphere.

Altimeter and radiometer data, combined with precise knowledge of the satellite's position, are used to obtain a detailed map of sea surface topography. From this, scientists calculate ocean current patterns and speeds.

Radar altimeters have also been used to determine the topography of Venus, most notably from the Magellan spacecraft. Its radio waves were able to penetrate Venus' thick cloud cover.
Reprinted from NASA JPL. *Fathometer in a Box,*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2meac1.pdf

Patterns showing the polar wandering paths for North America and Eurasia can be found in Prentice Hall (2002). Lutgens & Tarbuck Foundations of Earth Science. p.135.

For a detailed explanation of the Earth's magnetic field visit.
NOAA. *The Geomagnetic Field - Frequently Asked Questions.*
Available: http://www.ngdc.noaa.gov/seg//potfld/faqgeom.shtml

Lesson Description:

ENGAGE	As a class, label a diagram of Earth's internal structure: · solid inner core made of nickel and iron · liquid outer core · mantle containing minerals such as iron, magnesium, silicon, and oxygen · asthenosphere or upper mantle · lithosphere/crust. Introduce the idea that the lithosphere is made of two crustal types: oceanic crust made of the denser basalt and continental

	crust made of less dense rocks - granite and andesite. Technology Connection: View an animation of Continental Drift correlated to geologic time. University of Texas at Arlington. PaleoMap Project. *Continental Drift.* Available: http://www.ucmp.berkeley.edu/geology/anim4.html Do a KWL on Wegener's Theory of Continental Drift. 1. What is the Theory of Continental Drift? 2. What evidence did Wegener have to support his theory? · *Shape of the continents* · *Same index fossil organisms (that could not have crossed the oceans) were found on different continents* View a diagram showing location of index fossils. University of North Dakota. *VolcanoWorld. Continental Drift Fossils.* Available: http://volcano.und.nodak.edu/vwdocs/vwlessons/plate_tectonics/part3.html · *Same fossil plants were found on different continents* · *Similar patterns of rock layers on continents that stop on one continent and continue on another* · *Mountain ranges of similar age and type that stop on one continent and continue on another* · *Glacier remains in now- tropical landmasses.* Technology Connection: View animation of climate change linked to location of continents. Paleomap Project. *Paleoclimate animation.* Available: http://www.scotese.com/paleocli.htm

	Journal Write: Create a graphic organizer to record the evidence support Wegener's Theory of Continental Drift. Adaptive Strategy: Read to be informed about the Continental Drift theory. NASA. *Explanation of Continental Drift.* Available: http://kids.earth.nasa.gov/archive/pangaea/index.html Glencoe McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment, and the Universe. pp. 443-447. Prentice Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 118-121. Or other similar text passages may be used. ***Journal Write:*** 3. What were the objections to Wegener's theory? · *How did the continents move through solid rock?* · *What force could move the continents?* 4. Share with the class the fate of Wegener's theory. *Since Wegener didn't have a good answer to these questions the Theory of Continental Drift was largely ignored and by 1940 considered just about dead. Little did Wegener know that at the same time his theory was dying, advancements in technology would bring it back to life.*
EXPLORE	Give each pair of students a compass and a magnet. Think-Pair-Share: How can we use the compass to navigate around Earth? *Earth has a magnetic field with a north and south pole, very similar to a bar magnet.* Adaptive Strategy: For a basic explanation of magnetic fields and a simulation of how they work in a bar magnet, visit Windows to the Universe. *The Invisible World of Magnetic Fields.*

	Available: http://www.windows.ucar.edu/spaceweather/info_mag_fields.html For a more detailed explanation of magnetic fields, how they work in magnets and on Earth visit Don Reed. San JosZ State University. *Earth's magnetic field.* Available: http://geosun.sjsu.edu/105d/exped6/6.html Teacher Note: The magnetic poles are located close to the geographic north and south poles. What does a magnetic field look like? Materials per lab group: bar magnet, iron filings, paper Directions: 1. Spread the iron filings over the center of the paper. 2. Place the bar magnet under the paper. ***Journal Write:*** 3. Draw the arrangement of the iron filings after the magnet was place underneath them. 4. What caused the iron filings to move? 5. What does arrangement of the iron filings indicate? *The arrangement of the magnetic field.* 6. If Earth has a magnetic field similar to a bar magnet, predict what it look like. Teacher-led Discussion: 7. Show a picture of Earth's magnetic field. Windows to the Universe. *Earth's Magnetic Field.* Available: http://www.windows.ucar.edu/tour/link=/earth/images/field_image.html Materials per lab group: bar magnet, iron-rich mineral, such as magnetite

	8. Have students move the magnet over the iron-rich mineral. 9. What happens? Why does this occur? *Iron filings now locked in rock.* 10. Think about minerals on Earth. Basaltic lava contains high amounts of iron rich minerals (like magnetite). How will iron-rich minerals react to Earth's magnetic field? *They will align with the magnetic field.* Teacher Note: Show the transparency of the apparent polar wandering curves for Eurasia and North America. (See resources) *In the 1950s a study of the alignment of the magnetic minerals in old lava flows startled scientists. It indicated that Earth's magnetic North pole had not been relatively stationary, but instead had been located near Hawaii, moving to Siberia before it arrived at its position today near the North pole. This result was called Polar Wandering Curves.* Think-Pair-Share 1. Give each pair of students, two transparencies depicting the apparent polar wandering paths for Eurasia and for North America. 2. Examine the paths of the poles. 3. Do you think they moved? 4. If they did not move, is there another explanation for this data? 5. As a class discuss the evidence. *Conclusion: Since the geographic poles do not wander very much it is assumed that the magnetic poles don't wander too much either. An easier and simpler explanation is that the continents must have moved. This evidence shows that Continental drift is possible*

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EXPLAIN	***Journal Write:*** 1. What is the Continental Drift theory? 2. What evidence supports the theory? 3. How did the polar wandering curves support the theory? 4. Why was the theory rejected?
EXTEND	1. Share the following with students: *Another advancement in science was also taking place that would impact Wegner's theory.* *Before 1922, charts of the seafloor (bathymetric charts) were made from soundings. A weighted rope or chain was lowered from the ship until it reach bottom.* *But in 1922 a major advance occurred when the US Navy developed the echo sounder (or fathometer). The instrument, mounted on the ship or towed behind it, emits sound waves that bounce off the sea floor and return to the ship. The tool records the amount of time it takes the sound pulse to travel from the ship to the bottom and back again.* 2. Explain how the echo sounder works using a diagram of an echo sounder. Navy Meteorology and Oceanography Command Public Affairs. *The Underwater World.* Available: http://pao.cnmoc.navy.mil/pao/Educate/OceanTalk2/indexunderwater.htm Knowing the speed of sound in water (1500 m/s), the time it takes for the sound to reach the bottom (T), the depth (D) of the water can be calculated (D = S x T). 3. View a modern day echo sounder Meridata Finland Ltd. *Hydrographic echo sounder systems.*

Available: http://www.meridata.fi/

Materials per pair: graph paper

Working in pairs, students analyze data from an echo sounder to determine the depth of the ocean floor and generate an ocean profile.

Generating an Ocean Profile

Directions:

1. Using the information in the table, calculate the depth of the ocean floor using the following formula:

   D =1/2 T x V

   D= depth

   T = time in seconds

   V = Velocity or speed of sound in water 1524m/s

Journal Write:

2. Graph the data.
3. What underwater feature is shown? *Mid-ocean ridge or underwater mountain range.*

Adaptive Strategy: Model how to interpret the table and use the formula by plotting the first points. Allow students to use a calculator.

How ocean topography is measured today?

Read the introduction to TOPEX. This explains how satellites can measure features on the ocean floor.

JPL. NASA *Ocean Surface Topography from Space. HISTORY OF ALTIMETRY AND TOPEX/Poseidon*

Available: http://sealevel.jpl.nasa.gov/education/workshop.html

Adaptive Strategy: Preview new vocabulary terms prior to reading.

<table>
<tr><td></td><td><u>Technology Connection:</u>
View a simulation of an altimer in action.
JPL. NASA Ocean Surface Topography from Space. Technology. Available:
http://sealevel.jpl.nasa.gov/technology/technology.html
Journal Write:
1. How does an altimer work?
2. How can an altimer detect features on the ocean floor?
3. Examine the map of ocean topography. Before the echo sounder, scientists thought the floor of the ocean was flat and featureless. What does it really look like?

Read about Harry Hess and seafloor spreading. (See resources).
Discuss the article
1. Point out the flattened seamounts he called Guyots.
2. How did they become flattened? Wave erosion
3. How does the theory of seafloor spreading support Wegener’s theory of continental drift? Proposes that Earth is not solid rock and that continents can move.</td></tr>
<tr><td>EVALUATE</td><td>Journal Write:
1. Explain Wegener’s theory of Continental Drift.
2. Summarize the evidence that supports the theory continental drift.</td></tr>
</table>

Materials per lab group:

- Two compasses
- Iron filings
- Two pieces of magnetite
- Two bar magnets
- Two sheets of paper

- Graph paper
- Calculator
- Two transparencies of the polar wandering curve diagrams
- Diagram of Earth’s internal structure

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Generating an Ocean Profile

Directions:

1. Using the information in the table, calculate the depth of the ocean floor using the following formula:

$$D = 1/2\ T \times V$$

D= depth

T = time in seconds

V = Velocity or speed of sound in water 1524m/s

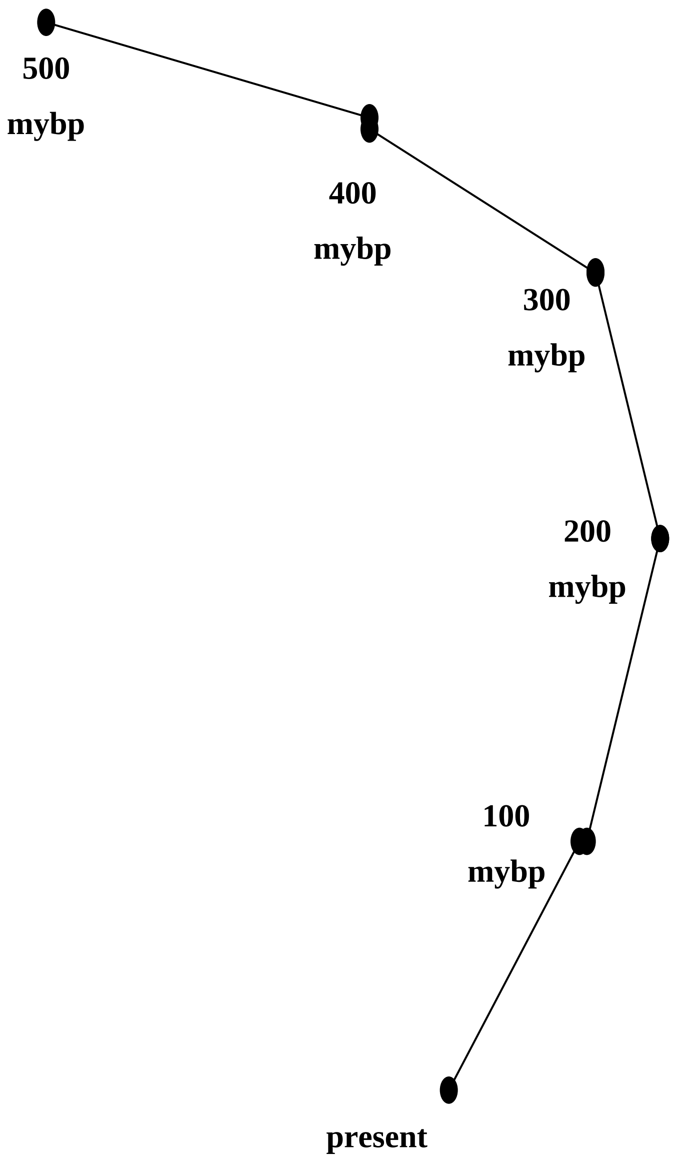
2. Graph the data.
3. What underwater feature is shown?

Ocean profile table

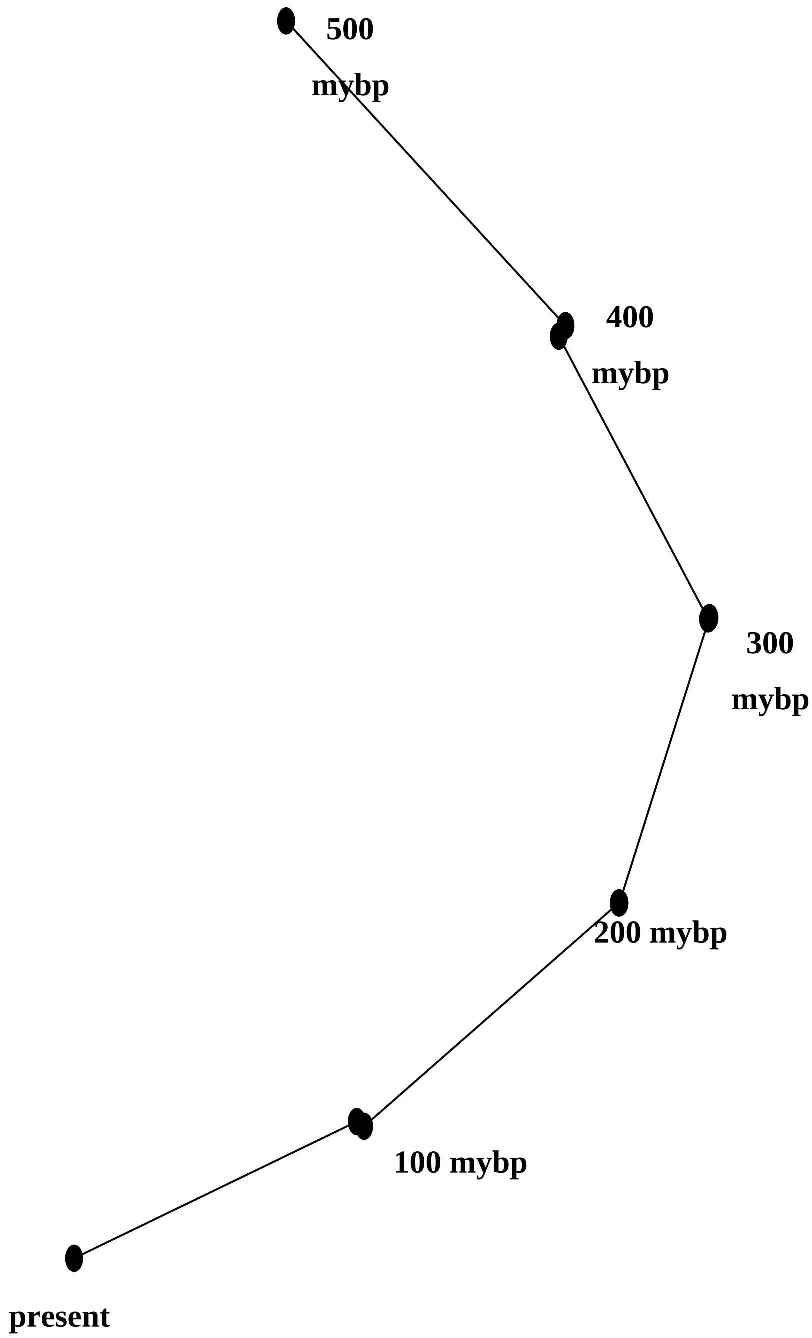
Surface Stations	Length of time for Signal to return to the ship (s)	Depth (m)
1	1.5	
2	3.7	
3	4.9	
4	5.2	
5	6.0	
6	8.7	
7	3.0	
8	2.4	
9	2.4	

Make transparencies of the two polar wandering curves.

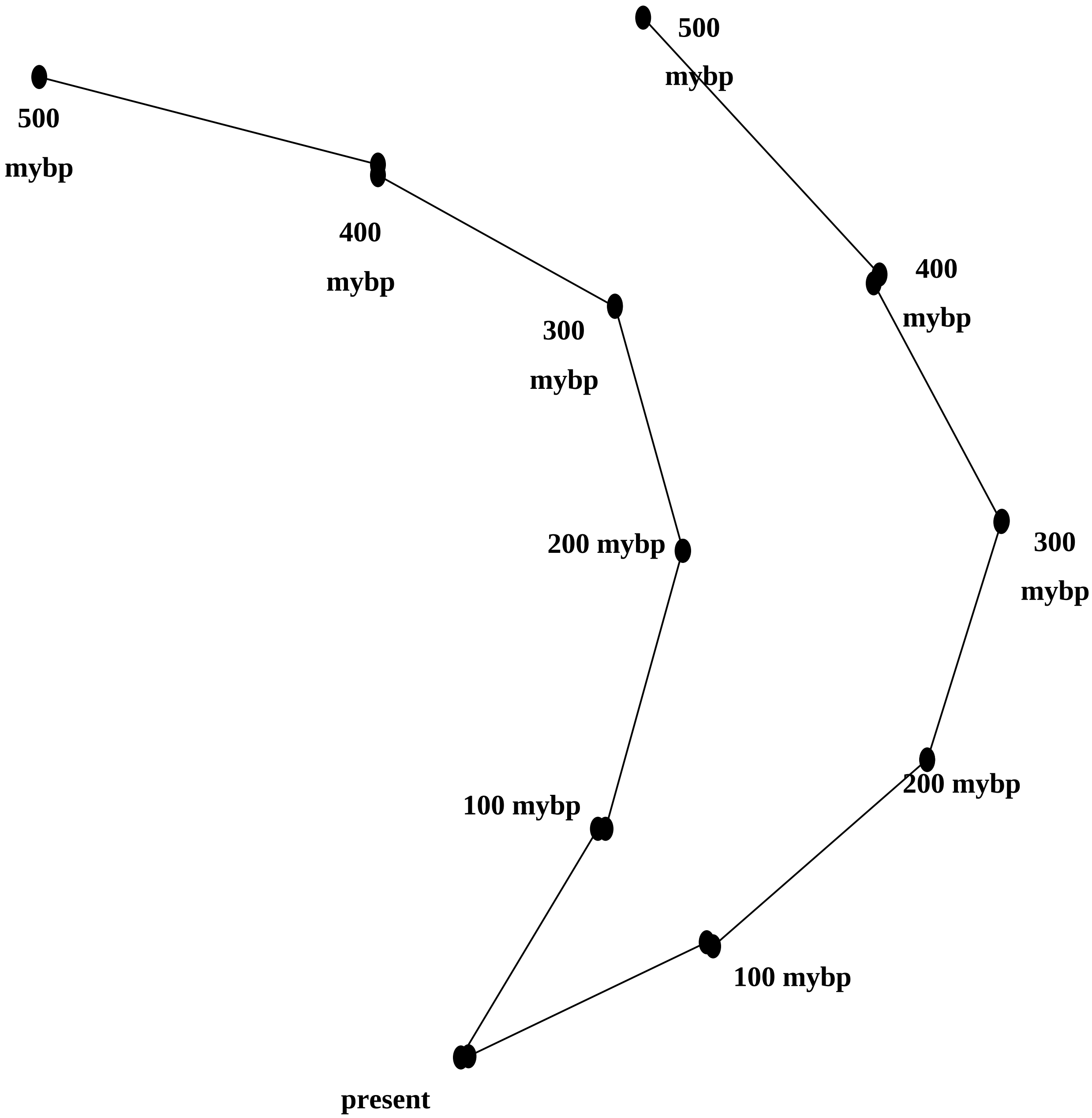
Diagrams of polar wandering curves.



This path represents changes in the location of Earth's magnetic north pole from a based on geomagnetic orientation of rocks found in Eurasia.



This path represents changes in the location of Earth's magnetic north pole from a based on geomagnetic orientation of rocks found in North America.



This path represents the apparent discrepancy in the location of Earth's magnetic north pole when the two geomagnetic records are superimposed. When the both continents are returned to their "Pangaean" orientation, the two lines become superimposed.

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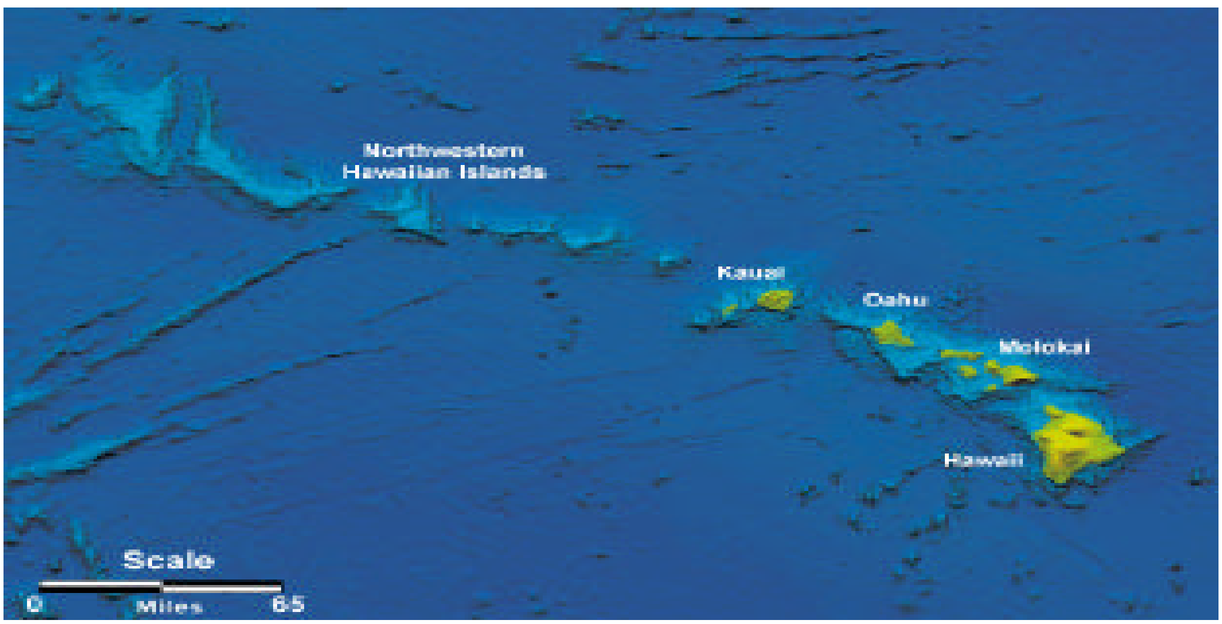
Harry Hess and Seafloor Spreading

Our story begins in World War II (1939-1945) when Dr. Hess, a geology professor at Princeton was called back to active duty. As Commander of the USS Cape Johnson, Hess decided to leave his fathometer (echo sounder) on 24 hours a day and map the ocean floor while he was performing his military duty of selecting landing sites for troop carriers at Iwo Jima. He discovered hundreds of flat-topped seamounts he called "guyots". He noticed that the tallest guyots were closest to the mid-ocean ridge.



Hess' research ultimately resulted in a groundbreaking hypothesis called Seafloor Spreading. In his paper, Hess proposed that molten rock (magma) oozes up from the Earth's interior along the mid-oceanic ridges, creating new seafloor that then spreads away from the ridge and, eventually, sinks into the deep oceanic trenches.

Cornell University. *Hawaii and Emperor Seamounts.*

Available: http://atlas.geo.cornell.edu/education/instructor/topography/hawaii_seamounts.html

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Lesson 15: SEAFLOOR SPREADING

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.3 The student will use experimental data from various investigators to validate results.

1.4.6 The student will describe trends revealed by data.

1.5.6 The student will read a technical selection and interpret it appropriately.

Indicator(s): Core Learning Goal 2

2.4.3 The student will explain changes in Earth's surface using plate tectonics.
Assessment limits (at least) - Continental drift (rock/structure/climate/fossil evidence, jigsaw fit) Sea floor spreading (age evidence, mantle circulation, outer core circulation/magnetic reversals, seismic activity, volcanism, mountain building, ocean ridges)

Student Outcome(s):

1. The student will be able to explain seafloor spreading by analyzing evidence that supports the theory.
2. The student will be able to describe how the sea floor is moving by diagramming the circulation patterns within the mantle and outer core.

Brief Description:

In this lesson, students investigate the dynamic internal processes occurring within Earth that are responsible for seafloor spreading and the movement of crustal plates.

Background knowledge / teacher notes:

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Convection in Earth: Thermal convection is inferred to exist on a large scale in at least two regions in Earth. The liquid outer core and the upper mantle behave as a solid for seismic wave propagation and as a very viscous fluid for long duration geologic processes including convection. The heat that causes convection within Earth comes from two sources – original heat from accretion and heat released during radioactive decay of unstable isotopes. Although Earth is about 4.5 billion years old, some heat remains from the accretionary process during its formation because fragments of Earth materials were heated to very high temperatures by impact during formation of the planet, and Earth materials have relatively low thermal conductivity so that significant heat has been retained from the early stages of Earth history. A more important source of heat, however, is the natural, spontaneous, radioactive decay of unstable isotopes of elements that are distributed throughout Earth, particularly in the crust and mantle. These radioactive elements include Uranium, Thorium and Rubidium. These sources of heat cause the Earth's temperature to increase with depth to a temperature of about 5000ŸC in the inner core.

Earth's outer core is inferred to be mostly liquid iron. Convective flow within the outer core not only brings heat to the core-mantle boundary where some of it is transferred into the mantle, but also causes Earth's magnetic field by motions of the electrically conductive inner core material. Temperatures are hot enough in the upper mantle _ 1200ŸC to cause thermal convection of the highly viscous upper mantle rocks, although the flow velocity is apparently very low - on the order of cm/yr. Mantle convection in either the upper mantle or the whole mantle has been suggested. The mantle flow is a likely cause of plate tectonic motions. There is still considerable debate about the details of convection in the mantle and the relationship of convection to plate tectonics. For example, there is evidence from the identification of subducted slabs in Earth's upper mantle, that lithospheric slabs (subducted plates) sometimes extend (penetrate) to depths greater than the upper mantle (below the mantle transition zone, including the 670 km discontinuity, where seismic wave velocity increases rapidly with depth indicating changes in composition or crystalline structure or "packing" of mantle minerals). Similarly, the exact relationship of mantle convection to plate motions is not presently known. Mantle convection could be the primary cause of plate tectonics. Alternatively, mantle convection could be a more passive response to plate motions. In either case, it appears clear that heat within Earth is the ultimate driving force for plate tectonics and mantle convection

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Purdue University. *Thermal Convection and Viscosity of a Fluid*

Available: http://www.eas.purdue.edu/~braile/edumod/convect/convect.htm

Lesson Description:

ENGAGE	Technology Connection: View animation of sea floor spreading. USGS. *Sea-floor spreading.* Available: http://wrgis.wr.usgs.gov/docs/parks/animate/A48.gif Adaptive Strategy: Orient students to the picture. Point out features such as the mid-ocean ridge, the crust and asthenosphere Describe to the person sitting next to you what is happening at the mid-ocean ridge. *New seafloor is being made at the ridge and the old seafloor is moving away from the ridge.* View a picture of an underwater lava flow. Woods Hole Oceanographic Institution. *Lava Flows Underwater.* Available: http://www.punaridge.org/doc/factoids/Eruptions/Default.htm Teacher-led Discussion: 1. Show a picture of the mid-Atlantic ridge with dimensions. USGS. *Topographic map of Mid-Oceanic Ridge.* Available: http://pubs.usgs.gov/publications/text/topomap.html *Called the global mid-ocean ridge, this immense submarine mountain chain -- more than 50,000 kilometers long and, in places, more than 800 km across -- zig-zags between the continents, winding its way around the globe like the seam on a baseball. Rising an average of about 4,500 meters above the sea floor, the*

	mid-ocean ridge overshadows all the mountains in the United States except for Mount McKinley (Denali) in Alaska (6,194 m). Though hidden beneath the ocean surface, the global mid-ocean ridge system is the most prominent topographic feature on the surface of our planet. 2. Examine a picture of seafloor spreading, but focus on the area of the trench. San Diego State University. *Subduction Zone Volcanism.* Available: http://www.geology.sdsu.edu/how_volcanoes_work/subducvolc_page.html 3. Describe to the person sitting next to you what is happening at the trench. *The oceanic crust (made of dense basalt) is meeting the less dense continental crust (made of granite and andesite). The oceanic crust is diving into mantle the below the continental crust.* Technology Connection: View an animation of trip down a trench. Seawifs. NASA. *Ocean Trench.* Available: http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/MOVIES/trench.mpg
EXPLORE	Discussion: 1. If theory of sea-floor spreading correct, what supporting evidence would you expect to find? *Hint: age of sea floor, thickness of sediment, earthquakes or tectonic activity* 2. List the predictions on the board or overhead.

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	Teacher Note – this site takes about 5 minutes to load. You may wish to preload to server. NOAA. *Crustal Age*. Available: ftp://ftp.ngdc.noaa.gov/MGG/images/WorldCrustalAge.gif 3. Examine the map of the age of the ocean floor. ***Journal Write***: 1. How old is the oldest rock on the sea floor? 2. Describe the relationship between the age of the ocean floor and ocean topography. 4. Examine the map showing sediment thickness on the ocean floor. NOAA. *Total Thickness Database*. Available: http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html ***Journal Write***: 1. How thick is the thickest sediment? 2. Describe the relationship between the thickness of the sediment deposits and ocean topography. A third piece of evidence was found in a study of magnetic material in the seafloor. A magnetometer, which measures small changes in the magnetic fields, was towed over the ocean floor. Technology Connection: 5. View the animation of mapping the seafloor. USGS. *Plate Tectonic Animations.* Available: http://www.aqd.nps.gov/grd/usgsnps/animate/A47.gif The pattern represents reversals in Earth's magnetic field.

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	Journal Write: What might have cause the pattern? JPL. NASA. *Plate Boundaries.* Available: http://scign.jpl.nasa.gov/learn/plate4.htm Adaptive Strategy: Help students interpret the animation. Orient them to the picture and discuss the pattern illustrates. Read about magnetic reversals Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment, and the Universe. pp. 415-452. Prentice Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 134-136. Or other similar text passages. ***Journal Write:*** 1. What are magnetic reversals? 2. How were they formed? 3. How do they support the theory of sea-floor spreading?
EXPLAIN	***Journal Write:*** 1. Describe the theory of sea-floor spreading. 2. Cite evidence to support the theory.
EXTEND	Teacher-led Discussion: 1. Give each student a map showing the mid-ocean ridge. 2. Where is new seafloor being formed? *mid-ocean ridge* 3. Where is it being lost? *trenches* 4. If new seafloor is being added at the mid-ocean ridges and lost at the trenches, what is causing the seafloor to move? What causes the circulation of air masses and water masses? *Differences in temperature and density.* 5. Are there differences in temperature and density inside Earth? View a cross section of the internal structure of earth.

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	MTV The Concord Consortium. *Dynamic Runnable Models Layers of Earth.* Available: http://mtv.concord.org/curriculum/dynamic-models/layers/layers.html Teacher Note: If this link does not work, use http://mtv.concord.org/curriculum/ And click on Dynamic Runnable Models located at the top of the page. 6. Point out the four layers of Earth. 7. Show a transparency of Table One: Characteristics of Earth's Internal Structure. (See resources). What trends are evident in the table? Technology Connection: 8. Start the animation of mantle circulation. Click on the Show Current button MTV The Concord Consortium. *Dynamic Runnable Models. Layers of Earth.* Available: http://mtv.concord.org/curriculum/dynamic-models/layers/layers.html Adaptive Strategy: Point out the color of the rising currents indicating their temperature and how they move the left or right, cool, change color and sink. Relate this movement to the two diagrams above showing a mid-ocean ridge (divergent boundary) and a trench (subduction boundary). ***Journal Write:*** 9. Diagram mantle circulation. On the diagram, label the mid-ocean ridge and trench. Identify the warm and cool currents. Read to be informed about mantle circulation. ***Journal Write:***

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	Create a graphic organizer to compare the different hypotheses about circulation: Convection cells vs. Slab-push and slab-pull Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment, and the Universe. pp. 460-463 Prentice Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 138-141. Or other similar text passages. 10. As a small group, discuss the two hypotheses of mantle circulation. Use the diagrams of mantle circulation to aid in the explanation. (See resources) Based on further research, scientist now know that mantle circulation is a little more complicated because it interacts with the outer core. Read about Outer Core Circulation. Space.com. *Dynamics of Earth's Core Reveal Hurricanes Under Your Feet.* Available: http://www.space.com/scienceastronomy/planetearth/core_cyclones_991110.html A good introduction to the idea of outer core circulation. ScienceDaily News. *Earth's Core May Contain "Cold Front" Of Molten Iron.* Available: http://www.sciencedaily.com/releases/1999/11/991118160149.htm Science News. *Scientists Eye Whirlpool in Earth's Core.* Available:

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	http://www.sciencenews.org/sn_arc99/11_13_99/fob5.htm A more complex article on outer core circulation. Teacher-led Discussion: Technology Connection: View a picture of the interaction between the outer core and mantel circulation. NASA. *Simulation of Earth's Core and Mantle.* Available: http://www-hpc.jpl.nasa.gov/NGCS/coremantle97.html Discuss the interaction between the mantle and outer core. Point out that the red plumes are warm currents and the blue plumes are cool currents. INTEREST CENTER Space.com. *Still Solo, Mars Global Surveyor Picks Up Slack in NASA's Mars Program.* Available: http://www.space.com/searchforlife/mars_globalsurveyor_991226.html Space.com. *Tracking Earth's Magnetic Field.* Available: http://www.space.com/scienceastronomy/generalscience/earth_poles_991027.html
EVALUATE	***Journal Write:*** 1. How does the theory of seafloor spreading support Wegener's theory of Continental Drift? Cite evidence from your reading. 2. Describe how the sea floor is moving by diagramming the circulation patterns within the mantle and outer core.

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Materials per lab group:

- Bathymetric map-four
- Transparency of Table One

Table One: Characteristics of Earth's Internal Structure

INTERNAL STRUCTURE	AVE. DENSITY	AVE. TEMPERATURE
LITHOSPHERE	3.0 g/cm^3	800°C
ASTHENOSPHERE	3.5 g/cm^3	1400°C
MANTLE	4.5 g/cm^3	2250°C
OUTER CORE	9.0 g/cm^3	4000°C
INNER CORE	11.5 g/cm^3	4800°C

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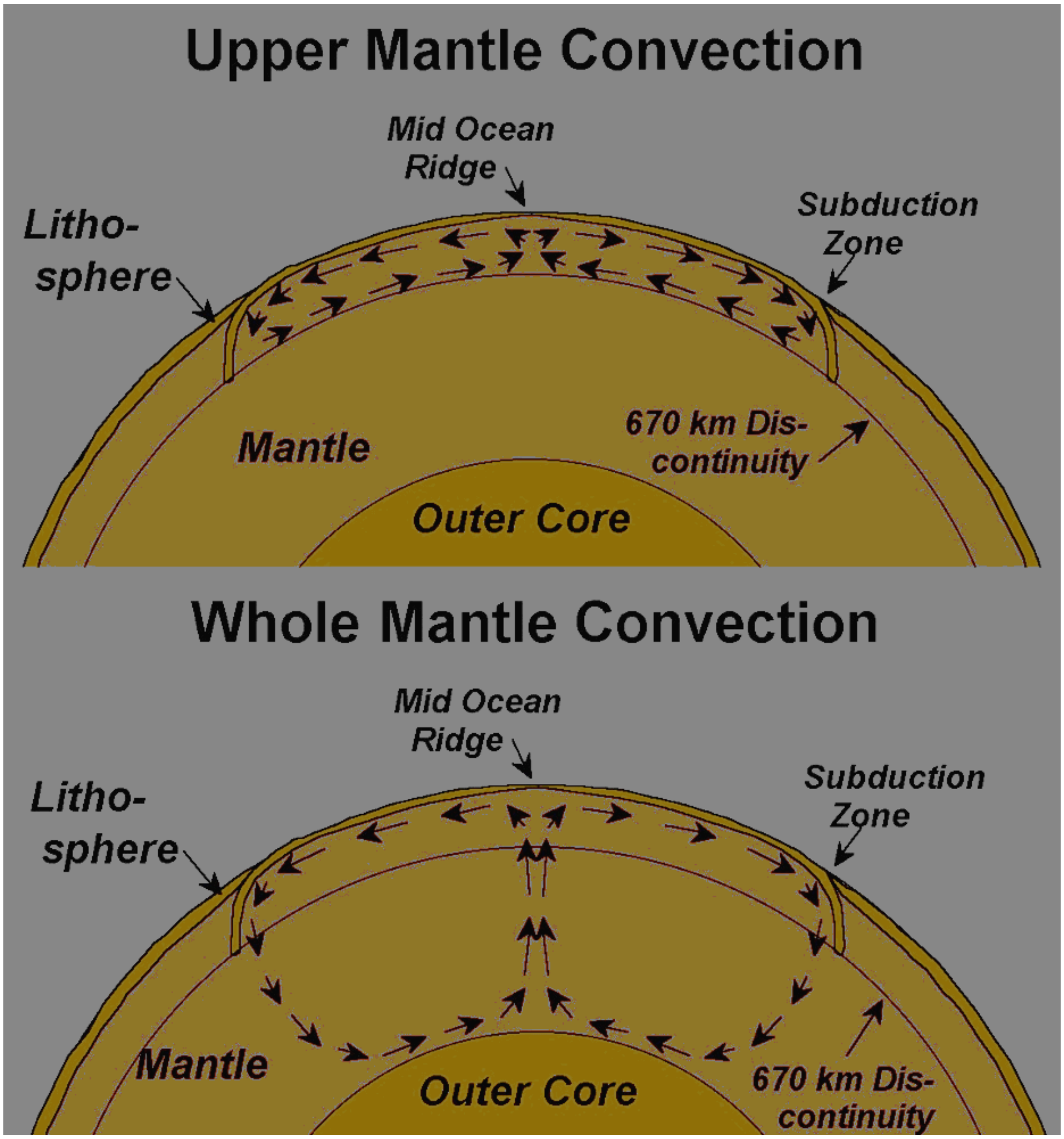
Hypothetical Cross-sections through Earth Showing Possible Patterns of Convection.



Upper diagram: Schematic diagram illustrating Slab-pull/Slab-push hypothesis for convection in Earth's upper mantle.

Lower diagram: Schematic diagram illustrating the Convection Cell hypothesis for convection in Earth's mantle in which the convection cell and related flow operate throughout the mantle.

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Lesson 16: METAMORPHISM AND THE ROCK CYCLE

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.5.2 The student will explain scientific concepts and processes through drawing, writing, and/or oral communication.

1.5.7 The student will use, explain, and/or construct various classification systems.

1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.

1.5.9 The student will communicate conclusions derived through a synthesis of ideas.

Indicator(s): Core Learning Goal 2

2.4.1 The student will compare the origin and structure of igneous, metamorphic and sedimentary rocks. Assessment limits (at least) - Origin, texture (crystal size, shape) and mineral composition of common rock groups

2.4.2 The student will explain how the transfer of energy drives the rock cycle. Assessment limits (at least) - Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition)

Student Outcome(s):

1. The student will be able to identify the origin, texture, and mineral composition of metamorphic rocks by conducting a laboratory investigation and reading a technical passage.
2. The student will be able to analyze metamorphism in subduction zones by reading a technical passage.
3. The student will be able to summarize the materials and processes of the rock cycle by creating a systems diagram.

Brief Description:

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In this lesson, students investigate characteristics of metamorphic rocks, along with the process of metamorphism, by performing a simulation activity. By combining this information with their knowledge of igneous and sedimentary rocks, they create a systems diagram that depicts the materials, processes, products, and multiple pathways of the rock cycle.

Background knowledge / teacher notes:

"Metamorphism of Sedimentary Rocks: When sedimentary rocks are buried to depths greater than about 5 to 10 km, they experience high enough pressures and temperatures to metamorphose into new rocks. Metamorphism is a rearrangement of all the elements that make up the minerals found in a rock, in order to produce a new set of minerals that are closer to being in equilibrium at these elevated temperatures and pressures. This rearrangement occurs by slow, solid-state diffusion of atoms -- no melting is involved in this process. It happens that at these high temperatures and pressures, the rocks become weaker and any forces acting on the rocks will cause them to deform, and this deformation leads to the alignment of minerals. This alignment gives the rocks a fabric in the form of foliated, banded, or lineated textures. Deep burial is one way of obtaining the heat necessary for metamorphism; heat from magma is another important agent in metamorphism and since magma production on the continents is associated with volcanic arcs and subduction zones, a great deal of metamorphism also occurs near convergent plate boundaries.

Melting of Metamorphic Rocks: Metamorphic rocks can either remain as metamorphic rocks, or they can follow one of three paths -- melting, uplift and weathering, or subduction. Melting is simply the result of continued heating and leads to the production of magma and thus new igneous rocks when the magma cools.

Metamorphic Rock Subduction: Any rocks that get caught up in the dynamics of a subduction zone may eventually get dragged down along with the subducting oceanic plate and as they get dragged down, they undergo metamorphism. Some sizable fraction of these rocks probably end up getting taken all the way down into the mantle, where they slowly mix with the rest of the mantle. This process is about the only way that rocks formed on the continents get recycled with the mantle."

From Dept. of Geology. Carleton College. *Modeling Earth's Rock Cycle.*

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Available:

http://www.acad.carleton.edu/curricular/GEOL/DaveSTELLA/Rock%20Cycle/rock_cycle.htm#sedmet

Metamorphic rocks are commonly classified by:

Bulk composition (and nature of source rock)

- Classification by bulk composition and nature of source rocks
- Grain size and fabric development

Classification by Texture

	Grain Size		
	Fine	**Medium**	**Coarse**
Poorly Foliated	hornfels	granofels marble quartzite amphibolite	granofels marble quartzite amphibolite
Well Foliated	slate, phyllite	schist	gneiss
Well Foliated and Sheared	mylonite	mylonite schist	augen gneiss

From Department of Geological Sciences. University of British Columbia. *Metamorphic Rocks.* Available: http://www.science.ubc.ca/~geol202/meta/metamorphic.html

Lesson Description:

ENGAGE	Technology Connection: View an animation of a subduction zone. PBS Online. Savage Earth. *Subduction Animation.* Available: http://www.pbs.org/wnet/savageearth/animations/index.html Discussion: 1. What is it like in a subduction zone? *Very hot, high pressure* 2. What happens to the rocks in the oceanic crust as they enter a

	subduction zone? *Some melt and become magma, but others do not get hot enough to melt, but do become deformed. They become metamorphic rocks.*
EXPLORE	Students perform an activity to simulate metamorphism in rocks. Materials per lab group: 2 slices white bread, 2 slices wheat or other dark bread, hand lens, metric ruler, wax paper, 2 bricks or a stack of books, microwave oven (optional) Metamorphism in Rocks Directions: 1. Design a data table to record your observations and measurements. 2. Using the hand lens, carefully observe the texture of the white bread and the wheat bread. ***Journal Write:*** 3. Record your observation in the data table. 4. Using the ruler, measure each slice of bread. ***Journal Write:*** 5. Record your observations in the data table. 6. Stack the four slices of bread; alternate white and dark. 7. Wrap the stacked slices of bread in wax paper. 8. Place bricks, a stack of books, or other weighted object on top of the wax paper. 9. If available, place the wax paper and bread in a microwave oven for 30 – 60 seconds. While waiting for the results of the experiment, read to be informed about Metamorphism. Glencoe McGraw-Hill. (2002). <u>Glencoe Earth Science: Geology, the Environment, and the Universe</u>. pp. 133-135. Prentice-Hall. (2002). <u>Lutgens & Tarbuck Foundations of Earth</u>

	Science. p. 48. Or, a similar text passage may be used. Discussion: 1. What is metamorphism? 2. How does metamorphism occur? 10. Unwrap the bread. ***Journal Write:*** 11. Remeasure the slices. 12. Describe any changes that occurred. 13. What forces are responsible for changes in the bread? 14. Predict how rocks might change when they are exposed to extreme heat and pressure. Adapted from Coal Education. *Metamorphic Sandwiches.* Available: www.coaleducation.org/lessons/sme/elem/9.htm Read about the texture of metamorphic rocks. Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment, and the Universe. p.135 Or Prentice-Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 48-49. Or, a similar text passage may be used. ***Journal Write:*** Describe the characteristics of metamorphic rocks. Working in small groups, students observe the characteristics of metamorphic rocks. Materials per lab group: Foliated (banded rocks) – gneiss, schist, slate, Nonfoliated (no bands) – quartzite, marble, hand lens

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<table>
<tr><td></td><td>
Metamorphic Rocks
Directions:
1. Separate the rock samples into two categories based on your observations.
Journal Write:
2. What characteristics did you use to divide the rocks into two groups?
3. Create a data table to record the characteristics of each rock: grain size, fabric, and color.
Provide students with following characteristics of metamorphic rocks.
Grain size
Metamorphic rocks with large grains generally indicate formation under high temperature and pressure. Note whether the grains are all the same size or have different sizes.
Fabric
Fabric is systematic structural alignment of grains in the rock. In gneiss, the fabric can be seen as layers of different minerals. In phyllite, the fabric may be visible as planes upon which the rock is easily split. Others, such as quartzite, may not have any fabric at all.
Color
Color is not as reliable an indicator as it is in igneous rocks, but it should be noted. For example, a soft, dull, black phyllite probably contains a fair amount of graphite, which may indicate original deposition as a black shale
From Civil and Environmental Engineering Berkeley. Metamorphic Rocks.
Available: http://www.ce.berkeley.edu/~khazai/CE70/metamorph.html
</td></tr>
<tr><td>EXPLAIN</td><td>Journal Write:</td></tr>
</table>

	1. Explain how the investigation with bread simulated metamorphism. Use evidence from your observations and reading. 2. At the end of your experiment, did the bread resemble a foliated or a nonfoliated metamorphic rock? Cite evidence from your results and from your reading. 3. How were you able to tell the difference between foliated and nonfoliated metamorphic rocks?
EXTEND	In small groups brainstorm: · the three major categories of rocks · where they are found · how they are formed · what happens to them. Using a diagram of seafloor spreading, create a systems diagram of the rock cycle. UCMP. Berkeley. *A Model of Seafloor Spreading Teacher's Guide.* Available: http://www.ucmp.berkeley.edu/fosrec/Metzger3.html Adaptive Strategy: Using the diagram of the rock cycle, describe how rocks are being affected. University of British Columbia. *The Rock Cycle.* Available: http://www.science.ubc.ca/~geol202/rock_cycle/rockcycle.html ***Journal Write:*** 1. What is happening to the crustal plates in this part of the diagram? 2. What conditions in this region lead to the formation of metamorphic rocks? 3. According to the rock cycle, what changes can metamorphic rocks undergo? 4. Where are igneous rocks formed? 5. What processes create sedimentary rocks?

	<u>G/T Connection:</u> Visit James Madison University. Department of Geology and Environmental Sciences. *Synopsis of Plate Tectonic Theory*. Available: http://geollab.jmu.edu/Fichter/PlateTect/synopsis.html Also, visit Texas Memorial Museum of Science and History at UT Austin. *Metamorphism and Sedimentary Processes.* Available: http://www.tmm.utexas.edu/npl/mineralogy/Mineral_Genesis/Metamorphism.htm ***Journal Write:*** 1. Why is metamorphism a common occurrence at subduction zones? 2. Create a graphic organizer comparing regional metamorphism and contact metamorphism. INTEREST CENTER USGS. *Collecting Rocks* Available: http://pubs.usgs.gov/gip/collect1/collectgip.html
EVALUATE	***Journal Write***: 1. How do foliated metamorphic rocks differ from nonfoliated metamorphic rocks? What causes these differences? 2. Why does metamorphism occur at subduction zones? 3. Create a systems diagram to illustrate the processes and products of the rock cycle.

Materials per lab group:

- 2 slices white bread
- 2 slices wheat or other dark bread
- Hand lens

- Metric ruler
- Wax paper
- 2 bricks or a stack of books
- Microwave oven (optional)
- Foliated (banded) rocks – e.g., gneiss, schist, slate
- Nonfoliated (no bands) rocks – e.g., quartzite, marble

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Metamorphism in Rocks

Directions:

1. Design a data table to record your observations and measurements.
2. Using the hand lens, carefully observe the texture of the white bread and the wheat bread.

Journal Write:

3. Record your observation in the data table.

4. Using the ruler, measure each slice of bread.

Journal Write:

5. Record your observations in the data table.
6. Stack the four slices of bread; alternate white and dark.
7. Wrap the stacked slices of bread in wax paper.
8. Place bricks, a stack of books, or other weighted object on top of the wax paper.
9. If available, place the wax paper and bread in a microwave oven for 30 – 60 seconds.
10. Unwrap the bread.

Journal Write:

11. Remeasure the slices.
12. Describe any changes that occurred.
13. What forces are responsible for changes in the bread?
14. Predict how rocks might change when they are exposed to extreme heat and pressure.

Metamorphic Rocks

Directions:

1. Observe the characteristics rocks.
2. Based on your observations, separate the rock samples into two categories.

Journal Write:

3. What characteristics did you use to divide the rocks into two groups?
4. Create a data table to record the characteristics of each rock: grain size, fabric, and color.

Characteristics of Metamorphic Rocks.

Grain size

Metamorphic rocks with large grains generally indicate formation under high temperature and pressure. Note whether the grains are all the same size or have different sizes.

Fabric

Fabric is systematic structural alignment of grains in the rock. In gneiss, the fabric can be seen as layers of different minerals. In phyllite, the fabric may be visible as planes upon which the rock is easily split. Others, such as quartzite, may not have any fabric at all.

Color

Color is not as reliable an indicator as it is in igneous rocks, but it should be noted. For example, a soft, dull, black phyllite probably contains a fair amount of graphite, which may indicate original deposition as a black shale

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Lesson 17: EARTHQUAKES: TIME-TRAVEL GRAPHS AND EPICENTERS

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.5.3 The student will use computers and/or graphing calculators to produce the visual materials (tables, graphs, and spreadsheets) that will be used for communicating results.

1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

Indicator(s): Core Learning Goal 2

2.1.2 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth.
Assessment limits (at least) –Techniques (imaging, Geographic Information System, Global Positioning System, spectroscopy, Doppler, epicenter location/time-travel graphs)

Student Outcome(s):

1. The student will be able to interpret a time-travel graph by analyzing P and S wave data.
2. The student will be able to determine the location of an epicenter by comparing the arrival times of P and S waves.

Brief Description:

In this lesson, students investigate earthquakes by analyzing time-travel graphs and completing computer simulation activities. By comparing arrival times of P and S waves at various seismograph locations, they locate the epicenter of an earthquake.

Background knowledge / teacher notes:

Earthquakes can be the most devastating and terrifying of natural hazards. Although floods, tornadoes and hurricanes account for much greater annual loss in the United States, severe earthquakes pose the largest risk in terms of sudden loss of life and property. Many interrelated factors determine the extent of loss of property and life from an earthquake. Each of the following should be prefaced with "all other factors being equal. . . ."

Amount of seismic energy released: The greater the vibrational energy, the greater the chance for destruction.

Duration of shaking: This is one of the most important parameters of ground motion for causing damage.

Depth of focus, or hypocenter: The shallower the focus (the point of an earthquake's origin within the earth), usually the greater the potential for destructive shock waves reaching the earth's surface. Even stronger events of much greater depth typically produce only moderate shaking at ground level.

Distance from epicenter: The potential for damage tends to be greatest near the epicenter (the point on the ground directly above the focus), and decreases away from it.

Geologic setting: A wide range of foundation materials exhibits a similarly wide range of responses to seismic vibrations. For example, in soft unconsolidated material, earthquake vibrations last longer and develop greater amplitudes, which produce more ground shaking, than in areas underlain by hard bedrock. Likewise, areas having active faults are at greater risk.

Geographic and topographic setting: This characteristic relates more to secondary effects of earthquakes than to primary effects such as ground shaking, ground rupture, and local uplift and subsidence. Secondary effects include land- slides (generally in hilly or mountainous areas), seismic sea waves, or tsunamis (pretty much restricted to oceans and coastal areas), and fires (from ruptured gas lines and downed utility lines).

Population and building density: In general, risk increases as population and building density increase. Types of buildings: Wooden frame structures tend to respond to earthquakes better than do more rigid brick or masonry buildings. Taller buildings are more vulnerable than one- or two-story buildings when located on soft, unconsolidated sediments, but taller buildings tend to be the more stable when on a hard bedrock foundation.

Time of day: Experience shows there are fewer casualties if an earthquake occurs in late evening or early morning because most people are at home and awake and thus in a good position to respond properly.

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Although earthquakes have been the objects of study and superstition for many centuries, the modern science of seismology gained impetus after the famous San Francisco earthquake of 1906. Since then, geologists have learned much more about the structure and composition of the Earth's interior and, more recently, have made progress in earthquake forecasting and in hazard and risk mitigation.

Origin of Earthquakes: Most earthquakes occur when great stresses building up within the Earth are suddenly released. This sudden release of this stored energy causes movement of the earth's crust along fractures, called faults, and generates shock waves. These shock waves, or seismic waves, radiate in all directions from the focus, much as ripples radiate outward in two dimensions when a pebble is dropped into a pond.

The two basic types of seismic waves are body waves, or primary waves, which travel through the interior of the earth, and surface waves, which travel along the earth's surface and are believed to be responsible for most earthquake damage.

There are two types of body waves: P waves, or primary waves, and S waves, or secondary waves. The faster moving P waves are compressional waves, and the slower S waves are shear waves. Compressional waves involve a "push-pull" vibration of Earth material in the same direction as the P waves are moving. In contrast, shear waves "shake" material at right angles to their path. Differences in P- and S-wave characteristics have provided much information about the structure and composition of the earth's interior.

Most earthquakes are shallow (0-40 miles to the focus), occurring in the lithosphere. The mechanism for most very shallow earthquakes probably involves fracturing of brittle rock in the crust or relief of internal stresses due to frictional resistance locking opposite sides of a fault.

Measuring Earthquakes: The vibrations produced by earthquakes are detected and recorded by instruments called seismographs. The time of occurrence, the duration of shaking, the locations of the epicenter and focus, and estimates of the energy released can be obtained from data from seismographs set up around the world.

Measurement of the severity of an earthquake can be expressed in several ways, the two most common being intensity and magnitude. The intensity, reported on the Modified Mercalli Intensity (MMI) Scale, is a subjective measure in terms of eyewitness accounts. Intensities are ranked on a 12-level scale and range from barely perceptible (I) to total destruction (XII). The lower intensities are described in terms of people's reactions and sensations, whereas the higher intensities relate chiefly to observable structural damage.

Magnitude is an objective measure of earthquake severity and is closely related to the amount of seismic energy released at the focus of an earthquake. It is based on the amplitude of seismic waves as recorded on standardized seismographs. The standard for magnitude measures is the Richter scale, an open-ended scale expressed in whole numbers and decimal fractions. The Richter scale is logarithmic, meaning that an earthquake of magnitude 5.0 has 10 times the wave amplitude of a magnitude 4.0 and 100 times the ground vibration amplitude of a magnitude 3.0 event. As a first approximation, each whole number increment on the Richter scale corresponds to a release of about 31 times more seismic, or vibrational, energy. Actually, there are several different methods of determining Richter magnitude. One uses surface waves, another body waves, and so on. However, the differences in results are slight.

Although the Richter scale has no upper limit, the greatest magnitude on record is 8.9 for earthquakes that occurred off the northwest coast of South America in 1906 (magnitude estimated) and off the east coast of Honshu, Japan in 1933. By comparison, the famous San Francisco earthquake of 1906 had an estimated magnitude of about 8.3 and an MMI of X.

Approximate relationships among earthquake magnitude, intensity, worldwide occurrence, and area affected (after U.S. Geological Survey, 1981, 1989).

General Description	Richter Magnitude	Modified Mercalli Intensity	Expected Annual Incidence	Distance Felt (miles)
Microearthquake	below 2.0	–	600,000	–
Perceptible	2.0-2.9	I–II	300,000	–
Felt generally	3.0-3.9	II-III	49,000	15
Minor	4.0-4.9	IV-V	6,000	30
Moderate	5.0-5.9	VI-VII	1,000	70

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Large (Strong)	6.0-6.9	VII-VIII	120	125
Major (Severe)	7.0-7.9	IX-X	18	250
Great	8.0-8.9	XI-XII	1.1	450

A comparison of the Modified Mercalli and the Richter Scales is shown in the table. As a general rule of thumb, damage is slight at the magnitude 4.5 level, becomes moderate at about 5.5, and above 6.5 or so can range from considerable to nearly total (Bollinger et al., 1989).

From Earthquakes in Maryland by James P. Reger
Reprinted courtesy of the Maryland Geological Survey with permission from D.W. Shelton.
Available: http://www.mgs.md.gov/esic/brochures/earthquake.html
Note: Charts and graphs omitted here. See website for complete article.

Lesson Description:

ENGAGE	Show students damage caused by earthquakes. USGS. *Largest Earthquakes in the United States.* Available: http://neic.usgs.gov/neis/eqlists/USA/1964_03_28_pics.html Discussion: 1. What caused this damage? 2. Do a KWL about earthquakes.
EXPLORE	Read to be informed about earthquake waves and time-travel graphs. ***Journal Write:*** Create a graphic organizer to compare types of earthquake waves and body waves. Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment, and the Universe. pp. 498-501. Prentice Hall. (2002). Lutgens & Tarbuck Foundations of Earth

	Science. pp. 149-151. Or other similar text passages. Adaptive Strategy: Use a slinky or other spring toy to demonstrate the difference between compressional P-waves and side-to-side S-waves. For instructions for an earthquake lab with slinkies visit: Exploratorium: *Seismic Slinky.* Available: http://www.exploratorium.edu/faultline/activities/slinky_activity.html Technology Connection: View the animation of P and S waves. PBS Online. *Savage Earth Animation. Earthquake!* Available: http://www.pbs.org/wnet/savageearth/animations/earthquakes/main.html Add information about P and S waves to your graphic organizer.
EXPLAIN	***Journal Write:*** 1. What causes an earthquake? *Pressure on a fault causes the fault to give. This sends seismic waves into the surrounding rock* 2. How is an earthquake related to plate tectonics? *Plate boundaries are areas of pressure.* 3. What are the differences between a P wave and an S wave? *P or Primary waves travel faster than S or Secondary waves. P-waves compress the rock through which they travel, while S-waves distort its shape or shear it. P-waves can travel through fluid, although they are slowed by it, but S-waves cannot*
EXTEND	Technology Connection: Working in pairs students analyze P and S waves and create a time-travel graph and determine the epicenter and magnitude of an earthquake. Earthquake: Time-Travel Graphs and Epicenters

	Directions: 1. Go to Geology Labs On-line. *Virtual Courseware. Earthquake.* Available: http://www.sciencecourseware.com/eec/Earthquake/ Listed under main activities, click on Tutorials. 2. Click on S-P wave button to see how to analyze seismic data. 3. Press the Start button to begin the simulation. 4. Press the Start button again to view data from two stations. 5. Press the Index button to return. 6. Click on the Latitude and Longitude button. Teacher Note: Students that understand latitude and longitude should omit this section. 7. Click on Close window button and return to the main window. Time-Travel Activity Adaptive Strategy: Model how to use the folders, record information in the journal and use the buttons to move to the next task. 1. Press on the Time-Travel Activity button. Teacher Note: While the activity is loading a permission to load Java script window may appear, you have permission! Just press the Yes button. 2. Press on the Assignment folder. 3. Read the instructions in the Assignment window and begin the five tasks. 4. Use the Journal window to record your information, graph the data and answer the questions. 5. When you have completed the activities, be sure to save your work. Click the Save button at the top of the page. 6. Print a copy of your work. 7. Press the Quit button at the top of the page. You will return to the Main page. Earthquake: Epicenter and Magnitude Activity

	1. Click on the Earthquake: Epicenter and Magnitude page 2. Read the instructions in the Assignment window and begin the five tasks. 3. Use the Journal window to record your information, graph the data and answer the questions. 4. When you have completed the activities, be sure to save your work. Click the Save button at the top of the page. 5. Print a copy of your work. 6. Press the Quit button at the top of the page. This will return you to the Main page. INTEREST CENTER USGS. *Earthquake Hazard Program. ANSS Recent Earthquake Activity in the USA.* Available: http://earthquake.usgs.gov/recenteqsUS/
EVALUATE	***Journal Write:*** 1. How do scientists use time-travel graphs to determine the epicenter of an earthquake? 2. Explain how P and S waves are used to determine the location of an epicenter.

Materials per lab group:

- Slinky

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Earthquake: Time-Travel Graphs and Epicenters

Directions:

1. Go to Geology Labs On-line. *Virtual Courseware. Earthquake.*
2. Available: http://www.sciencecourseware.com/eec/Earthquake/
3. Listed under main activities, click on Tutorials.
4. Click on S-P wave button to see how to analyze seismic data.
5. Press the Start button to begin the simulation.
6. Press the Start button again to view data from two stations.
7. Press the Index button to return.
8. Click on the Latitude and Longitude button.
9. Click on Close window button and return to the main window.

Time-Travel Activity

1. Press on the Time-Travel Activity.
2. Press on the Assignment folder.
3. Read the instructions in the Assignment window and begin the five tasks.
4. Use the Journal window to record your information, graph the data and answer the questions.
5. When you have completed the activities, be sure to save your work. Click the Save button at the top of the page.
6. Print a copy of your work.
7. Press the Quit button at the top of the page. This will return you to the Main page.

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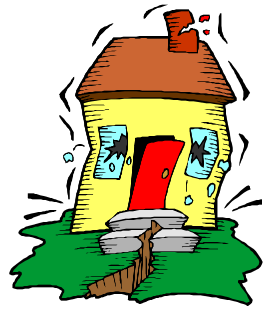
Earthquake: Epicenter and Magnitude Activity



1. Click on the Earthquake: Epicenter and Magnitude page
2. Read the instructions in the Assignment window and begin the five tasks.
3. Use the Journal window to record your information, graph the data and answer the questions.
4. When you have completed the activities, be sure to save your work. Click the Save button at the top of the page.
5. Print a copy of your work.
6. Press the Quit button at the top of the page. You will return to the Main page.

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Lesson 18: THEORY OF PLATE TECTONICS

Estimated Time: Two blocks

Indicator(s): Core Learning Goal 1

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.3 The student will formulate a working hypothesis.

1.3.4 The student will learn the use of new instruments and equipment by following instructions in a manual or from oral direction.

1.5.3 The student will use computers and/or graphing calculators to produce the visual materials (tables, graphs, and spreadsheets) that will be used for communicating results.

1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.

1.6.4 The student will manipulate quantities and/or numerical values in algebraic equations.

Indicator(s): Core Learning Goal 2

2.1.2 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth.
Assessment limits (at least) – Techniques (imaging, Geographic Information System, Global Positioning System, spectroscopy, Doppler, epicenter location/time-travel graphs)

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) - Destructive processes (weathering, erosion, subsidence, melting) Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition) Landform change (surface & groundwater, coasts, glacial processes, desert processes)

2.4.3 The student will explain changes in Earth's surface using plate tectonics.
Assessment limits (at least) Sea floor spreading (age evidence, mantle circulation, outer core circulation/magnetic reversals, seismic activity, volcanism, mountain building, ocean ridges) Theory of Plate Tectonics (crustal plate composition, mantle circulation, divergent/convergent/transform fault boundaries, subduction zones, trenches, island arcs, seismic activity, volcanism, mountain building)

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Student Outcome(s):

1. The student will be able to compare transform, divergent, and convergent plate boundaries by reading a technical selection and conducting a simulation.
2. The students will be able to locate plate boundaries by evaluating tectonic activity.

Brief Description:

In this lesson, students investigate plate tectonics through reading technical passages and performing a simulation activity. They also use the computer program ArcView to study the relationship between plate boundaries and seismic events, e.g., earthquakes and volcanoes.

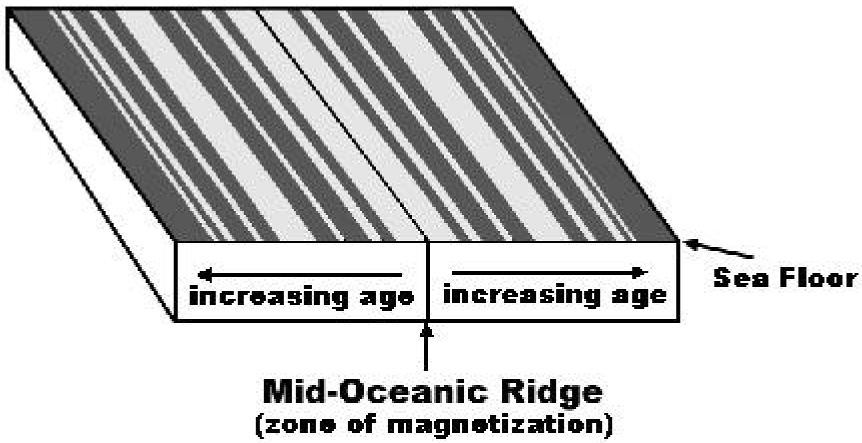
Background knowledge / teacher notes:

"Plate tectonics is a relatively new theory that has revolutionized the way geologists think about the Earth. According to the theory, the surface of the Earth is broken into large plates. The size and position of these plates change over time. The edges of these plates, where they move against each other, are sites of intense geologic activity, such as earthquakes, volcanoes, and mountain building. Plate tectonics is a combination of two earlier ideas, continental drift and sea-floor spreading.

The main features of plate tectonics are:

- The Earth's surface is covered by a series of crustal plates.
- The ocean floors are continually, moving, spreading from the center, sinking at the edges, and being regenerated.
- Convection currents beneath the plates move the crustal plates in different directions.
- The source of heat driving the convection currents is radioactivity deep in the Earths mantle.

The mid-oceanic ridges rise 3000 meters from the ocean floor and are more than 2000 kilometers wide surpassing the Himalayas in size. The mapping of the seafloor also revealed that these huge underwater mountain ranges have a deep trench that bisects the length of the ridges and in places is more than 2000 meters deep. Research into the heat flow from the ocean floor during the early 1960s revealed that the greatest heat flow was centered at the crests of these mid-oceanic ridges.



Seismic studies show that the mid-oceanic ridges experience an elevated number of earthquakes. All these observations indicate intense geological activity at the mid-oceanic ridges.

Geomagnetic Anomalies

Periodically, the Earth's magnetic field reverses. New rock formed from magma records the orientation of Earth's magnetic field at the time the magma cools. Study of the sea floor with magnometers revealed "stripes" of alternating magnetization parallel to the mid-oceanic ridges. This is evidence for continuous formation of new rock at the ridges. As more rock forms, older rock is pushed farther away from the ridge, producing symmetrical stripes to either side of the ridge. In the diagram to the right, the dark stripes represent ocean floor generated during "reversed" polar orientation and the lighter stripes represent the polar orientation we have today. Notice that the patterns on either side of the line representing the mid-oceanic ridge are mirror images of one another. The shaded stripes also represent older and older rock as they move away from the mid-oceanic ridge. Geologists have determined that rocks found in different parts of the planet with similar ages have the same magnetic characteristics.

Deep Sea Trenches: The deepest waters are found in oceanic trenches, which plunge as deep as 35,000 feet below the ocean surface. These trenches are usually long and narrow, and run parallel to and near the oceans margins. They are often associated with and parallel to large continental mountain ranges. There is also an observed parallel association of trenches and island arcs. Like the mid-oceanic ridges, the trenches are seismically active, but unlike the ridges they have low levels of heat flow. Scientists also began to realize that the youngest regions of the ocean floor were along the mid-oceanic ridges, and that the age of the ocean floor increased as the distance from the ridges increased. In addition, it has been determined that the oldest seafloor often ends in the deep-sea trenches.

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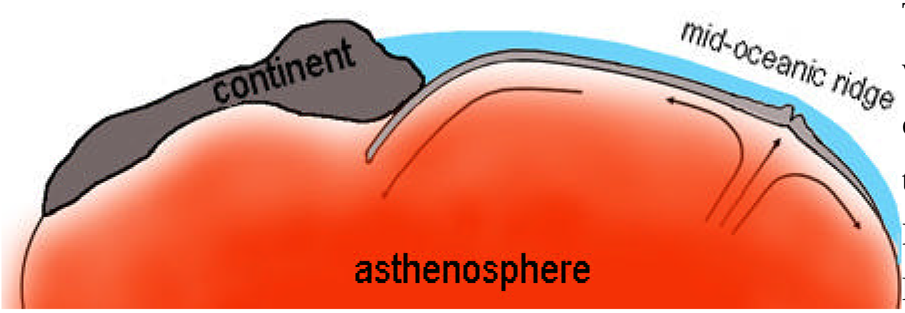
Island Arcs: Chains of islands are found throughout the oceans and especially in the western Pacific margins; the Aleutians, Kuriles, Japan, Ryukus, Philippines, Marianas, Indonesia, Solomons, New Hebrides, and the Tongas, are some examples.. These "Island arcs" are usually situated along deep sea trenches and are situated on the continental side of the trench.



These observations, along with many other studies of our planet, support the theory that underneath the Earth's crust (the lithosphere: a solid array of plates) is a malleable layer of heated rock known as the asthenosphere which is heated by radioactive decay of elements such as Uranium, Thorium, and Potassium. Because the radioactive source of heat is deep within the mantle, the fluid asthenosphere circulates as convection currents underneath the solid lithosphere. This heated layer is the source of lava we see in volcanoes, the source of heat that drives hot springs and geysers, and the source of raw material which pushes up the mid-oceanic ridges and forms new ocean floor. Magma continuously wells upwards at the mid-oceanic ridges (arrows) producing currents of magma flowing in opposite directions and thus generating the forces that pull the sea floor apart at the mid-oceanic ridges. As the ocean floor is spread apart cracks appear in the middle of the ridges allowing molten magma to surface through the cracks to form the newest ocean floor. As the ocean floor moves away from the mid-oceanic ridge it will eventually come into contact with a continental plate and will be subducted underneath the continent. Finally, the lithosphere will be driven back into the asthenosphere where it returns to a heated state."

From University of California Berkeley. Museum of Paleontology. *Plate Tectonics – The Mechanism.*

Available: http://www.ucmp.berkeley.edu/geology/tecmech.html

Lesson Description:

ENGAGE	How fast is the seafloor spreading? To find out, do the activity - Seafloor Spreading in the Atlantic Ocean.

	Materials per lab group: metric ruler-2, calculator-2, seafloor map-2, geologic time scale-2 (See resources). Directions: 1. On your map of the seafloor, locate the thin line that runs along the margins of the continents. This line represents the continental shelf. The boldface line labeled "0" represents the Mid-Atlantic Ridge. The lines on either side of the ridge represent strips of seafloor basalt. The numbers on these lines represent the ages of the seafloor in millions of years. 2. Point A and Point B on the map are 4,550 km apart. Using this information, create a realistic scale for your map. 3. Observe the numbered lines on either side of the ridge ***Journal Write:*** 4. Is the rate of seafloor spreading constant throughout Earth's history? Cite evidence from your map to support your answer. 5. Select one strip of basalt on the seafloor for your investigation. ***Journal Write:*** 6. What is the age of your strip seafloor? 7. Using your scale, determine the distance from your strip of seafloor to the mid-Atlantic ridge. (map distance in cm x map scale = distance in km) 8. Using the age of your seafloor strip and its distance from the mid-Atlantic ridge, calculate the half-rate of seafloor spreading. 9. Calculate the total rate (velocity) of seafloor spreading by multiplying your answer by 2. (distance in km / time in My) x 2 = total rate (velocity) 10. Using this rate and the distance between points A and B (4,550 km) determine the age of the Atlantic Ocean.

	11. Using your geologic time scale, identify the geologic time period when the Atlantic Ocean formed. ***Journal Write:*** 12. How much has the distance (in cm) between North America and Africa increased since you were born? 13. How much closer (in cm) were these two continents when Columbus made his voyages? Adapted from Department of Geosciences, Pennsylvania State University. *The Distance Between Us and Them: Sea Floor Spreading in the Atlantic Ocean.* Available: http://www.beloit.edu/~SEPM/Earth_Works/Sea_floor_spreading.html.
EXPLORE	Read to be informed about the Theory of Plate Tectonics. SCIGN Education Module. *Plate Tectonics.* Available: http://scign.jpl.nasa.gov/learn/plate3.htm Adaptive Strategy: Remind students that they may access terminology of underlined words by clicking on the term. As a small group, discuss the following questions: 1. What is the theory of plate tectonics? *Study of the motion and deformation of Earth's crustal plates.* 2. What assumptions is the theory based on? *New material is generated by sea-floor spreading and old seafloor is lost at the trenches. Motion of plates is accommodated at plate boundaries.* Plate Boundaries Materials per lab group: 4 blocks of clay, aluminum foil Directions: 1. Cover two blocks of clay with aluminum foil. Make two blocks taller than the others. The taller blocks represents the continental crust. The shorter blocks represent the oceanic crust. 2. Brainstorm what happens when two plates meet. What types of interactions are possible?

	3. Create a data table to record the interactions between the different types of plates. 4. Push the two plates together. ***Journal Write:*** 5. Diagram the interaction and record what happens to the edges of the plates. 6. What feature(s) does this represent? 7. Adaptive Strategy: Brainstorm possible interactions as a class. Model one type of plate interaction. Point out how the edges of the plates are affected. ***Journal Write:*** 8. Predict where on Earth this type of boundary is located. 9. Smooth out the blocks. Brush the two plates passed each other. Observe the area of contact and record your observations. Read to be informed about the types of plate boundaries. PBS Online. A Science Odyssey. *Mountain Maker, Earth Shaker*. Available: http://www.pbs.org/wgbh/aso/tryit/tectonics/ Create a graphic organizer comparing divergent, convergent, and transform plate boundaries. Adaptive Strategy: For a more accessible version of this information, visit Enchanted Learning. *Continental Drift.* Available: http://www.enchantedlearning.com/subjects/dinosaurs/glossary/Contdrift.shtml G/T Connection: USGS, This Dynamic Earth. *Understanding plate motions.* Available: http://pubs.usgs.gov/publications/text/understanding.html#anchor6715825

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EXPLAIN	***Journal Write***: 1. Refer to the results of your laboratory simulations. What types of plate boundaries did you model? Cite evidence from your reading to support your answer. 2. How are plate boundaries responsible for the construction and destruction of crustal material?
EXTEND	Technology Connection: Teacher Note: Students must have a working knowledge of ArcView before beginning this activity. Using Earthquakes and Volcanoes to Plot Plate Boundaries Directions: 1. Go to Start, Programs and Choose Arc View GIS 3.2a. 2. Create a new View. 3. Click OK. 4. To add data, click the Yes button. 5. Choose the Earth Space folder. 6. Choose the Quake Data folder. 7. Hold down the shift key and select all files. 8. Click OK. 9. In the View window, turn on Continent.shp. 10. Make all the continents white. Click on Continents in the Table of Contents. Open the Legend Editor. Change Legend Type to Single Symbol: choose white as the color. *Journal Write:* 11. Write a hypothesis predicting the location of earthquakes. 12. Now turn on Quak2000.shp. *Journal Write:* 13. How does the pattern of earthquakes support theory of plate tectonics? 14. Look at areas that have the highest concentration of earthquakes.

	What do they have in common? 15. Click the Query button. Select earthquakes with a depth of ≥ 300. Press New Set. 16. In the Query box, delete the depth information. Select earthquakes of a magnitude ≥ 6. Press the Add to set button. Close the window. *Journal Write:* 17. Where in the world are the most severe earthquakes concentrated? 18. What type of plate boundary is probably most responsible for these earthquakes? 19. Go to Theme pull-down menu and Clear all selected features. 20. Click on the Quake theme in the Table of Contents and open Legend Editor. Change Legend type to Graduated Color. Change Classification Field to Depth. At the bottom of the screen change Color Ramps to Full Spectrum. Click the Apply button. 21. Use the Zoom button and zoom in on the West coast of South America. 22. Locate an area that has both shallow (red) and the deepest earthquakes (purple). 23. Using the Identify tool (i), find and record the identification and depth of both earthquakes. (Numbers are shown in kilometers.) *Journal Write:* 24. What do these differences in depth suggest about the type of plate movement in this area? 25. Turn off the Quake theme. *Journal Write:* 26. Write a hypothesis predicting the location of volcanoes. 27. Click on the Volcano theme. 28. Click on the Query button. Double click on Type. Single click the = sign. Double click Active. Click New Set. *Journal Write:*

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29. Where are most active volcanoes located?
30. Turn on the Quak2000.shp. theme.
31. Describe the relationship between the locations of earthquakes and volcanoes.
32. Predict the location of plate boundaries.
33. Turn on plate outlines by clicking on Plates.shp. in the Table of Contents.

Journal Write:

34. How many major plates are evident?
35. Where is the largest plate located?

G/T Connection:

36. Repeat step 23, then use the Measure button to find the distance between the two earthquakes. Double-click to quit the measurement tool. (Note: the distances between earthquakes are given in miles, but depths are given in kilometers.) To convert miles to kilometers, divide the miles by 0.6. Using this information, calculate the downward angle of the plate between these two earthquakes.

For example: Quake 9172 = depth 33km

Quake 9175 = depth 562 km

The distance between them is 655 miles. 655/.6 = 1092 km

T= (562-33)/1092 = .4844 and inverse tan .4844 = 26 degrees.

INTEREST CENTER

USGS NEIC: *Earthquake Hazards Program Last 30 days of earthquake activity.*

Available: http://gldss7.cr.usgs.gov/neis/qed/qed.html

Zbigniew Zwolinski. *The Great Globe Gallery.*

	Available: http://hum.amu.edu.pl/~zbzw/glob/glob28.htm
EVALUATE	***Journal Write***: 1. Compare the three types of plate boundaries. Cite evidence from your reading and the simulation. 2. Describe the relationship between plate boundaries and tectonic activity. Use evidence from your simulation.

Materials:

- Blocks of clay
- Aluminum foil
- ArcView Computer Program
- Ruler-2,
- Calculator-2,
- Seafloor map-2,
- Geologic time scale-2

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Seafloor Spreading in the Atlantic Ocean

Background

Seafloor spreading is a major part of the theory of plate tectonics. According to this concept, new crustal material is formed at plate boundaries found on the ocean floor. These boundaries are called mid-ocean ridges. The most prominent boundary of this type is the Mid-Atlantic Ridge. Along the mid-Atlantic ridge, lava or new rock is added to the edges of the North American, South American, African, and Eurasian plates. As a result, the Atlantic Ocean is slowly widening and the two sets of continents move apart.

The youngest seafloor rocks are found in the middle of the mid-Atlantic ridge; where these rocks were formed. As you move away from the ridge toward the continental shelves, the rocks are older. By analyzing magnetic properties of rocks collected at various distances from the ridge, geologists can determine the rate at which new seafloor is formed.

1. On your map, locate the thin line that runs along the margins of the continents. This line represents the continental shelf. The boldface line labeled “0” represents the Mid-Atlantic Ridge. The lines on either side of the ridge represent strips of seafloor basalt. The numbers on these lines represent the ages of the seafloor in millions of years.
2. Point A and Point B on the map are 4,550 km apart. Using this information, create a realistic scale for your map.
3. Observe the numbered lines on either side of the ridge

Journal Write:

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4. Is the rate of seafloor spreading constant throughout Earth's history? Cite evidence from your map to support your answer.
5. Select one strip of basalt on the seafloor for your investigation.

Journal Write:

6. What is the age of your strip seafloor?
7. Using your scale, determine the distance from your strip of seafloor to the mid-Atlantic ridge.

   (map distance in cm x map scale = distance in km)
8. Using the age of your seafloor strip and its distance from the mid-Atlantic ridge, calculate the half-rate of seafloor spreading.
9. Calculate the total rate (velocity) of seafloor spreading by multiplying your answer by 2.

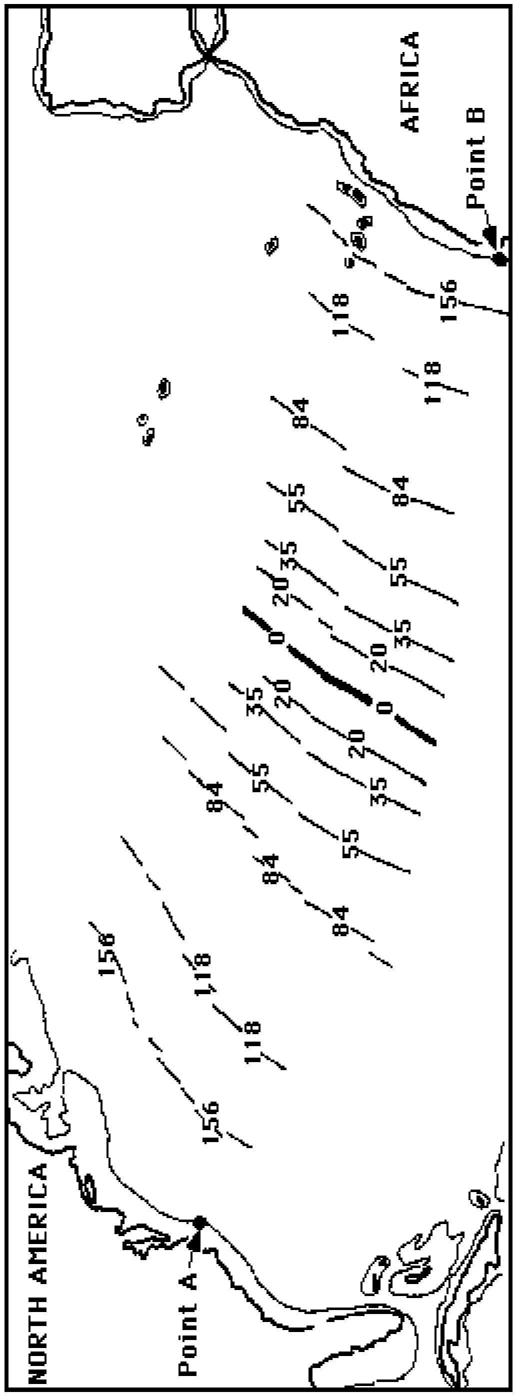
   (distance in km / time in My) x 2 = total rate (velocity)
10. Using this rate and the distance between points A and B (4,550 km) determine the age of the Atlantic Ocean.
11. Using your geologic time scale, identify the geologic time period when the Atlantic Ocean formed.

Journal Write:

12. How much has the distance (in cm) between North America and Africa increased since you were born?
13. How much closer (in cm) were these two continents when Columbus made his voyages?

Department of Geosciences, Pennsylvania State University. *The Distance Between Us and Them: Sea Floor Spreading in the Atlantic Ocean.* Available:

http://www.beloit.edu/~SEPM/Earth_Works/Sea_floor_spreading.html.



Strip map of a portion of the North Atlantic region showing the coastlines and continental shelf edges of North America and Africa. The bold line labelled "0" is the Mid-Atlantic Ridge. Selected strips of sea floor basalt on either side of the ridge are labelled with their ages in millions of years. The approximate distance between Point A and Point B is 4,550 kilometers.

THE GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH	APPROXIMATE AGES (in millions of years)
CENOZOIC	Quaternary	Recent Pleistocene	1.6
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	65
MESOZOIC	Cretaceous		144
	Jurassic		208
	Triassic		245
PALEOZOIC	Permian		285
	Pennsylvanian		320
	Mississippian		360
	Devonian		408
	Silurian		438
	Ordovician		505
	Cambrian		540
PRECAMBRIAN			> 4550

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Using Earthquakes and Volcanoes to Plot Plate Boundaries

Directions:

1. Go to Start, Programs and Choose Arc View GIS 3.2a.
2. Create a new View.
3. Click OK.
4. To add data, click the Yes button.
5. Choose the Earth Space folder.
6. Choose the Quake Data folder.
7. Hold down the shift key and select all files.
8. Click OK.
9. In the View window, turn on Continent.shp.
10. Make all the continents white. Click on Continents in the Table of Contents. Open the Legend Editor. Change Legend Type to Single Symbol: choose white as the color.

Journal Write:

11. Write a hypothesis predicting the location of earthquakes.

12. Now turn on Quak2000.shp.

Journal Write:

13. How does the pattern of earthquakes support theory of plate tectonics?
14. Look at areas that have the highest concentration of earthquakes. What do they have in common?

15. Click the Query button. Select earthquakes with a depth of ≥ 300. Press New Set.
16. In the Query box, delete the depth information. Select earthquakes of a magnitude ≥ 6. Press the Add to set button. Close the window.

Journal Write:

17. Where in the world are the most severe earthquakes concentrated?
18. What type of plate boundary is probably most responsible for these earthquakes?

19. Go to Theme pull-down menu and Clear all selected features.
20. Click on the Quake theme in the Table of Contents and open Legend Editor. Change Legend type to Graduated Color. Change Classification Field to Depth. At the bottom of the screen change Color Ramps to Full Spectrum. Click the Apply button.
21. Use the zoom in button on the West coast of South America.
22. Locate an area that has both shallow (red) and the deepest earthquakes (purple).
23. Using the Identify tool (i), find and record the identification and depth of both earthquakes. (Numbers are shown in kilometers.)

Journal Write:

24. What do these differences in depth suggest about the type of plate movement in this area?

25. Turn off the Quake theme.

Journal Write:

26. Write a hypothesis predicting the location of volcanoes.

27. Click on the Volcano theme.
28. Click on the Query button. Double click on Type. Single click the = sign. Double click Active. Click New Set.

Journal Write:

29. Where are most active volcanoes located?
30. Turn on the Quak2000.shp. theme.
31. Describe the relationship between the locations of earthquakes and volcanoes.

32. Predict the location of plate boundaries.
33. Turn on plate outlines by clicking on Plates.shp. in the Table of Contents.

Journal Write:

34. How many major plates are evident?
35. Where is the largest plate located?

<u>G/T Connection:</u>

Repeat step 23, then use the Measure button to find the distance between the two earthquakes. Double-click to quit the measurement tool. (Note: the distances between earthquakes are given in miles, but depths are given in kilometers.) To convert miles to kilometers, divide the miles by 0.6. Using this information, calculate the downward angle of the plate between these two earthquakes.

For example: Quake 9172 = depth 33km

Quake 9175 = depth 562 km

The distance between them is 655 miles. 655/.6 = 1092 km

T= (562-33)/1092 = .4844 and inverse tan .4844 = 26 degrees.

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Lesson 19: MOUNTAIN BUILDING

Estimated Time: One block

Indicator(s): Core Learning Goal 1

1.1.3 The student will critique arguments that are based on faulty, misleading data or on the incomplete use of numbers.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.

Indicator(s): Core Learning Goal 2

2.4.2 The student will explain how the transfer of energy drives the rock cycle.
Assessment limits (at least) - Constructive processes (lithification, deformation, metamorphism, volcanism, cooling/crystallization, deposition)
Landform change (surface & groundwater, coasts, glacial processes, desert processes)

2.4.3 The student will explain changes in Earth's surface using plate tectonics.
Assessment limits (at least) - Theory of Plate Tectonics (crustal plate composition, mantle circulation, divergent/convergent/transform fault boundaries, subduction zones, trenches, island arcs, seismic activity, volcanism, mountain building)

Student Outcome(s):

1. The student will be able to describe how tectonic activity shapes the face of the Earth by investigating how mountains are formed.
2. The student will be able to predict changes in topographical features by analyzing the movement of plates.

Brief Description:

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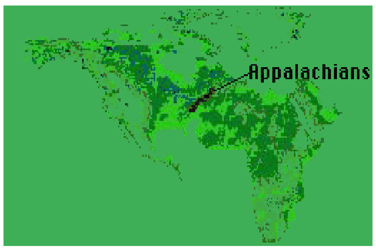
By comparing a topographic map with information on plate boundaries, students are asked to draw conclusions about relationships between plate tectonics and the formation of mountain ranges.

Background knowledge / teacher notes:

"The great mountain ranges of the world were created because of the constant but very slow movement of the Earth's plates. When the plates of the Earth collide, the crust folds into high mountain ranges. The roots of the world's great mountain ranges contain some of the oldest rocks on the surface of the Earth. Some of these rocks are over 3.5 billion years old! These rocks were once buried deep inside the Earth and have been raised into mountains by the collisions of the plates. These plates travel at a very slow rate about 1 to 4 inches per year. The Indian Subcontinent was a very fast mover, clipping along at over 4 inches per year. When it slammed into the Eurasian plate over 24 million years ago the collision built the highest mountain range in the world, the Himalayas. In fact, the Himalayas are still climbing higher and higher today. All rock that is put under extreme pressure for long periods of time (thousands or millions of years) will fold like clay.

Folding is a process in which the Earth's plates are pushed together in a roller coaster like series of high points and low points. Folding bends many layers of rocks without breaking them. The Appalachian Mountains and Rocky Mountains of the United States and the Alps of Europe are examples of mountain ranges that were formed by folding. Many of the greatest mountain ranges of the world have formed because of enormous collisions between continents. The Appalachian Mountains in the Eastern United States were formed about 400 million years ago when North America and Africa collided.



Mountains sometimes form when many layers of the Earth's crust are moved vertically upward at fault lines by pressures caused by plates colliding. Fault lines are great cracks in the crust. The mountains that are formed in this way are called *fault-block mountains.* The Sierra Nevada Mountains in California and Nevada, and the Grand Teton range of Wyoming are examples of fault-block mountains. The Black Hills of South Dakota and Wyoming, and the Adirondack Mountains of New York are low mountains that were formed when the crust was heaved upward without folding or faulting into a rounded dome. These are called *Dome Mountains.* Dome mountains are much higher in elevation than the surrounding land and because of this erosion occurs at a very fast rate."

Reprinted from VolcanoWorld. *Content Center Plate Movements.*
Available: http://volcano.und.nodak.edu/vwdocs/vwlessons/lessons/Ch1CMB/Content3.html

"The Absolute Plate Motion Calculator computes the velocity of a given point on a given plate relative to a hotspot reference system.

An example is as follows:

- For Chicago, Illinois, Latitude 44N, Longitude 87W
  Name of Plate = North America
  Angular velocity = -11.10 degree/million years
  Velocity = 2.55 cm
  Direction = 242.72 degrees

The Relative Plate Motion Calculator provides information about the movement of one plate with respect to an adjacent plate. Two adjacent plates are selected and the longitude and latitude for the point of contact. One plate is considered moving while the other is considered fixed. The results of the calculation show the velocity (in cm/year) and direction of the moving plate. Students may then draw a vector on a map showing the direction and speed of the moving plate. By reversing the fixed/moving plate data on the calculations, the student will see that the opposing plate's relative movement is at the same velocity in the opposite direction.

An example is as follows:

- For Latitude 32S, Longitude100W ...
  Relatively fixed plate = Pacific

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Relatively moving plate = Nazca

Angular Velocity = 1.42 degree/million years

Velocity = 15.77 cm

Direction = 95.58 degree

- For the same latitude/longitude but reversing the plates ...

Relatively fixed plate = Nazca

Relatively moving plate = Pacific

Angular Velocity = 1.42 degree/million years

Velocity = 15.77 cm

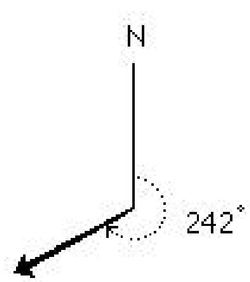
Direction = 275.59 degrees

Interpretation of data ...

The velocity and direction of the moving plate provide the information needed by the student to mark their maps. The latitude and longitude entered confirms the given location. Note that the direction of each plate's relative movement is the complement of the other, and the velocity is identical.

Scientists use vectors to represent plate motion on maps. A vector used in this situation is an arrow pointing in the direction of plate motion with a length proportional to the plate speed. Getting the arrow correct involves constructing an angle and a length.

- Since plates move a few centimeters per year, it is natural to make the arrow the same length as the plate movement. In the case of the absolute plate motion at Chicago, the arrow should be 2.55 cm in length.
- Because direction is given in degrees, a protractor is used to construct the angle corresponding to the plate's direction of movement. In the case of the absolute plate motion at Chicago, the arrow should point in a direction approximately 242 degrees (measured in a clockwise direction) from north."



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From Mathematical Sciences. Montana State University. *The Moving Plates.*

Available: http://www.math.montana.edu/~nmp/materials/ess/geosphere/inter/activities/plate_calc/

Lesson Description:

ENGAGE	Discussion: 1. Examine a topographic world map. The Mountain Forum. *Mountains of the World.* Available: http://www.mtnforum.org/resources/atlas/world.htm 2. What features are evident? *Mountain ranges* 3. Point out the mountain ranges, preview some of the names: *Alps, Appalachian, Himalayas, Rockies…* 4. Brainstorm how these mountain ranges were formed.
EXPLORE	Technology Connection: Features and Plate Boundaries Materials per lab group: world map with plate boundaries-4 Directions: 1. Go to Start, Programs and Choose Arc View GIS 3.2a. 2. Open an existing project. Choose the name of the file that shows the pattern of earthquakes, volcanoes and plate boundaries. 3. Click OK. 4. Make sure the continents and plates are turned on. 5. Turn on Features.shp. You may need to make this a different color in order for it to be easily seen. 6. On your world map, shade in where these features are located. Use different colors for different features. 7. Using the I key click on the features. Label the names of the

	Features ranges. 8. In the table, list the names of the mountain ranges, whether or not they are near an edge of a plate boundary, the type of plate boundary Geothermal Education Office. *Plate Boundaries Map.* Available: http://geothermal.marin.org/GEOpresentation/sld006.htm Read to be informed about how mountains are formed. Glencoe McGraw-Hill. (2002). Glencoe Earth Science: Geology, the Environment, and the Universe. pp. 529-538. Prentice Hall. (2002). Lutgens & Tarbuck Foundations of Earth Science. pp. 169-173. Or other similar text passages. ***Journal Write:*** Based on the information from your reading revise your graphic organizer as needed.
EXPLAIN	***Journal Write:*** 1. Compare methods of mountain formation. 2. Describe relationship between the formation of mountains and the types of plate boundaries.
EXTEND	Technology Connection: Working in small groups, students determine the absolute plate motion for selected cities. Teacher-led discussion: 1. Explain that Absolute Plate Motion is the motion of a specific location on a plate relative to fixed features (hot spots) in the Earth's underlying mantle. 2. Using the Chicago information, model how to input Latitude 44N, Longitude 87W= +44, -87

	3. Press the execute calculation button. 4. Results for Chicago, Illinois, Latitude 44N, Longitude 87W Name of Plate = North America Angular velocity = -11.10 degree/million years Velocity = 2.55 cm Direction = 242.72 degrees 5. Using the velocity, model how to draw the arrow. The length of the arrow is the velocity obtained from the Absolute Plate Motion Calculator, measured in centimeters. 6. Using your protractor, the direction and north as your starting point, determine the angle measurement. The "tail" of the arrow should be positioned on the city and the "head" should point from the city in the direction of plate motion. <u>Adaptive Strategy</u>: Model how to use a protractor. Reduce the number of cities each group is assigned. Provide the longitude and latitude data. Mountain Ranges and the Movement of Plates Directions: 1. Create a graphic organizer to record the following information for your cities: longitude and latitude, direction and speed of plate. 2. Using an Atlas or website find the longitude and latitude for your cities: infoplease.com. *Latitude and Longitude of World Cities.* Available: http://www.infoplease.com/ipa/A0001769.html Teacher Note: Suggested cities: Boston MS, Washington DC, Atlanta GA, Miami FL, Detroit MI, St. Louis MO, Kansas City KS, Houston TX, Denver CO, Santa Fe NM, Salt Lake City UT, Seattle WA, Reno NV, Sacramento CA 7. Next to each latitude rewrite to indicate North latitudes with a +

sign, South latitudes with a – sign. East longitudes with a + sign and West longitudes with a - sign

3. Go to Ocean Research Institute, University of Tokyo. *Absolute Plate Motion.*

Available: http://triton.ori.u-tokyo.ac.jp/~intridge/pmc/hs2_nuvel1.html

4. Using the Absolute Plate Motion Calculator, find the direction and velocity of plate motion at each city.
5. Record this information on your graphic organizer.
6. Using your protractor, draw a plate arrow for each city on your map of North America. The "tail" of the arrow should be positioned on the city and the "head" should point from the city in the direction of plate motion. The length of the arrow is the velocity measured in centimeters.

Adaptive Strategy: Using an overhead transparency, confirm the location, velocity and direction of each position so students can check their maps.

Journal Write:

7. Which of these cities is moving the fastest?
8. Is the east or west coast of the U.S. moving faster?
9. Does plate motion get faster or slower as you go towards the leading edge of the plate?
10. Why is it possible for different parts of the U.S. to move at different speeds?

11. Now investigate the velocity and direction of different continents.
12. Create a new graphic organizer.
13. Select a city on each continent. Record this information in your

	graphic organizer. 14. Go to Ocean Research Institute, University of Tokyo. *Absolute Plate Motion.* Available: http://triton.ori.u-tokyo.ac.jp/~intridge/pmc/hs2_nuvel1.html 15. Using the Absolute Plate Motion Calculator, find the direction and velocity of plate motion at each city. 16. Record this information on your graphic organizer. 17. Draw a plate arrow for each city on your world map. The "tail" of the arrow should be positioned on the city and the "head" should point from the city in the direction of plate motion. The length of the arrow is the number obtained from the Absolute Plate Motion Calculator, measured in centimeters. ***Journal Write:*** 18. Which plates are moving towards the North American plate? 19. Predict what arrangement of the continents will look like in the future. 20. Which mountain ranges will be taller? 21. Where will new mountain ranges form? Use evidence from the simulation to support your answers. Discussion: 1. Each group shares their predictions and evidence. 2. Why do the predictions differ? 3. Discuss how the data might be biased or incomplete. Technology Connection: View an animation of plate movements 250 million years in the future. Christopher Scotese. *Paleomap Project. Future VR* Available: http://www.scotese.com/futanima.htm

	<u>G/T Connection:</u> Teacher-led discussion: 1. Explain that Relative Plate Motion is the motion of one plate compared with respect to the motion of another plate. 2. Select a point on the boundary between two plates, such as 30N latitude and 43W longitude. 3. Go to Ocean Research Institute, University of Tokyo. *Relative Plate Motion.* Available: http://triton.ori.u-tokyo.ac.jp/~intridge/pmc/nuvel1a.html 4. Enter these data in the Relative Plate Motion Calculator, using +30 for latitude and -43 for longitude and selecting the North America plate as Relatively Fixed and the Africa plate as Relatively Moving. 5. The result, 2.28 cm/yr moving on a heading of 102.95 degrees, indicates that, from the perspective of an observer standing on the edge of the North America plate at that location, Africa is moving off to the southeast at 2.28 cm/yr. 6. Indicate this on the world map transparency using an arrow 2.28 cm in length having a reference angle of 103 degrees. Directions: 1. Go to Ocean Research Institute, University of Tokyo. *Relative Plate Motion.* Available: http://triton.ori.u-tokyo.ac.jp/~intridge/pmc/nuvel1a.html 2. Select a point on the boundary between two plates, such as 30N latitude and 43W longitude. 3. Record the information in your graphic organizer.

	4. As you complete each calculation, add arrows to your world map. ***Journal Write:*** 5. Which plate in contact with the North America plate is moving the fastest? 6. Which plates are moving towards the North American plate? 7. How many years would it take for each plate to move 1 meter? From Mathematical Sciences. Montana State University. *The Moving Plates.* Available: http://www.math.montana.edu/~nmp/materials/ess/geosphere/inter/activities/plate_calc/
EVALUATE	***Journal Write***: 1. Explain how mountains are formed. 2. What is the relationship between tectonic activity and the formation of mountains? 3. Using data from plate movements, predict which mountain ranges will become taller and where new mountain ranges might form.

Materials per lab group:

- World map with plate boundaries-4
- ArcView Computer program
- Map of North America-4
- Topographical world map

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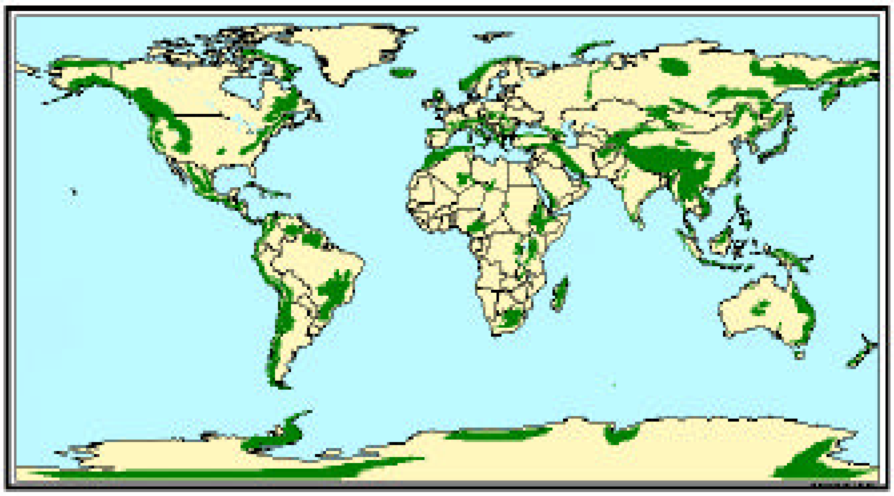
Features and Plate Boundaries



The Mountain Forum. *Mountains of the World.*
Available: http://www.mtnforum.org/resources/atlas/world.htm

Directions:

1. Go to Start, Programs and Choose Arc View GIS 3.2a.
2. Open an existing project. Choose the name of the file that shows the pattern of earthquakes, volcanoes and plate boundaries.
3. Click OK.
4. Make sure the continents and plates are turned on.
5. Turn on Features.shp. You may need to make this a different color in order for it to be easily seen.
6. On your world map, shade in where these features are located. Use different colors for different features.
7. Using the I key click on the features. Label the names of the Features ranges.
8. In the table, list the names of the mountain ranges, whether or not they are near an edge of a plate boundary, the type of plate boundary

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Name of Mountain Range	On Edge of Plate? Yes or No	Type of Plate Boundary	Predict how these mountains were formed.

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Mountain Ranges and the Movement of Plates

Directions:

1. Create a graphic organizer to record the following information for your cities: longitude and latitude, direction and speed of plate.
2. Using an Atlas or website find the longitude and latitude for your cities: infoplease.com. *Latitude and Longitude of World Cities*. Available: http://www.infoplease.com/ipa/A0001769.html
3. Go to Ocean Research Institute, University of Tokyo. *Absolute Plate Motion*. Available: http://triton.ori.u-tokyo.ac.jp/~intridge/pmc/hs2_nuvel1.html
4. Using the Absolute Plate Motion Calculator, find the direction and velocity of plate motion at each city.
5. Record this information on your graphic organizer.
6. Using your protractor, draw a plate arrow for each city on your map of North America. The "tail" of the arrow should be positioned on the city and the "head" should point from the city in the direction of plate motion. The length of the arrow is the velocity measured in centimeters.

Journal Write:

7. Which of these cities is moving the fastest?
8. Is the east or west coast of the U.S. moving faster?
9. Does plate motion get faster or slower as you go towards the leading edge of the plate?
10. Why is it possible for different parts of the U.S. to move at different speeds?

11. Now investigate the velocity and direction of different continents.
12. Create a new graphic organizer.
13. Select a city on each continent. Record this information in your graphic organizer.
14. Go to Ocean Research Institute, University of Tokyo. *Absolute Plate Motion.* Available: http://triton.ori.u-tokyo.ac.jp/~intridge/pmc/hs2_nuvel1.html
15. Using the Absolute Plate Motion Calculator, find the direction and velocity of plate motion at each city.
16. Record this information on your graphic organizer.
17. Draw a plate arrow for each city on your world map. The "tail" of the arrow should be positioned on the city and the "head" should point from the city in the direction of plate motion. The length of the arrow is the number obtained from the Absolute Plate Motion Calculator, measured in centimeters.

Journal Write:

18. Which plates are moving towards the North American plate?
19. Predict what arrangement of the continents will look like in the future.
20. Which mountain ranges will be taller?
21. Where will new mountain ranges form?
22. Use evidence from the simulation to support your answers.

From Mathematical Sciences. Montana State University. *The Moving Plates.* Available: http://www.math.montana.edu/~nmp/materials/ess/geosphere/inter/activities/plate_calc/